DOCUMENT RESUME

ED 224 696 SE 039 735

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TITLE	A Teacher's Guide to the Energy 80 Student Booklet for the 1981-82 School Year.
INSTITUTION	Enterprise for Education, Santa Monica, CA.
PUB DATE	Feb 81
NOTE	361p.; For related document (Student Booklet) see SE 039 392.
AVAILABLE FROM	Enterprise for Education, Suite 2134, 10960 Wilshire Blvd., Los Angeles, CA 90024.
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Conservation Education; Economics; *Energy; Energy Conservation; Environmental Education; *Fuels; Interdisciplinary Approach; Junior High Schools; Learning Activities; Nuclear Energy; *Power Technology; Science Activities; Science Education; *Secondary School Science; *Social Studies; *Solar Radiation
IDENTIFIERS	*Energy Education

ABSTRACT

This teaching guide was developed for use with Energy 80 program student booklets. Although the program was designed for junior high/middle school students in science/social studies classes, it is indicated that the materials are suitable for use at higher grades and, to a lesser extent, in upper elementary grades. The first 80 pages of the guide suggest ways of using the student booklet. Each of the 16 spreads in the student booklet deals with a separate topic, and the guide treats each spread separately. Included for each topic (spread) are objectives, reading level, background information, list of key vocabulary words, suggested activities and discussion topics, resources, and mini-quiz. The last three-quarters of the guide contains a selection of lesson plans, worksheets, and readings from the program, providing the basis for an interdisciplinary course in energy at the junior high school level. These materials are organized into eight units: energy fundamentals; energy from the sun; history and technology of fossil fuels; energy from nuclear fission; renewable energy resources; energy in the United States; economics and decision-making; and energy conservation. Rough outlines of two science and two social studies mini-units (using materials in the guide) are provided near the beginning of the guide. (Author/JN)

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ED224696

A Teacher's Guide to the Energy 80 student booklet

For the 1981-82 School Year

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John Lord

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Enterprise for Education, Inc. February, 1981

A Note to the Teacher

Here, in response to your request, is the first general distribution edition of ENERGY 80 materials. The generosity of businesses in your state made possible the printing and shipment of these materials to you. You might wish to know, however, that no corporate funding---or promise of funding---was obtained during the first years of the project. We are trying to make the program as comprehensive and unbiased as possible, and we look forward to hearing your reaction and learning how you used the materials.

WHAT YOU SHOULD HAVE RECEIVED

With this teacher's guide you should have received 30 copies of the booklet for students titled "ENERGY 80."

HOW THE TEACHER'S GUIDE IS ORGANIZED

The first 80 pages of this guide suggests ways of using the student booklet. Each of the 16 spreads (two facing pages) deals with a separate topic, and the guide treats each spread separately.

The last three-quarters of the book contains a selection of lesson plans, worksheets, and readings from the program. At appropriate points,the discussions of the spreads will refer you to materials in the rear of the book. But I hope you will take a few moments to browse through the appendix and get a feel for material's content and method.

WHAT YOU CAN DO

Of course , you could give students the booklet and ask them to read it. Results will be mixed, since students need time to digest the variety of ideas presented, and help in relating them to their own surroundings. You could deal with one spread a week over a semester. That would allow you to include some hands-on activities, which are extremely helpful.

You may choose to make use of a lesson or two within your existing course of study. Looking over the selection of lessons in this edition, I think you will find that particularly easy to do if you are teaching science or American History.

Some teachers will wish to consider teaching a mini-unit about energy using these materials. Rough outlines of four such units (two science, two social studies) are suggested near the beginning of the Guide.

WHEN YOU CAN EXPECT NEW MATERIALS

ENERGY 80 is intended to be improved annually. Each spring, funding permitting, we will send revised student and teacher materials to teachers who request them and who have helped to improve the materials. Spring shipment will give you a chance to examine the materials and to decide how best to use them in the coming year.

Besides incorporating revisions based on your comments and those of other teachers, the '82-'83 teacher's manual will include additional lesson plans. Many of these are in the units on renewable energy sources, economics and consumer decision making, and conservation. A number of these lessons are now circulating in draft form; I think you will find them interesting and useful.

WE NEED YOUR HELP

In two ways. First, this program is made possible by grants from a number of sponsors, a different set in each state. They would like to know what you think of the ENERGY 80 program, and specifically whether the materials are really being used and are helpful to you. Secondly, we need to know what changes and additions would be most helpful to you. To make this review and evaluation as easy as possible, a questionnaire on a prepaid business reply form labeled "A TEACHER'S REACTION TO ENERGY 80" is included at the rear of this book. Please examine the materials. Use them in the classroom this spring if you have the opportunity. And then, please, mail us your reply card no later than June 1, 1981. If you can take the time to write us a letter with more detailed comments, that would be very much appreciated.

ORDERS FOR THE NEXT EDITION OF ENERGY 80 DUE JUNE 1, 1981

New materials for the 1982-83 school year will again be available free of charge. The order form for these materials has deliberately been put on the same business reply form as the evaluation questionnaire. Without your help, we can neither improve the materials nor raise the funding. So no evaluation, no materials.

> No request for materials from a school previously provided with materials can be honored if a completed evaluation has not been returned.

IN-SERVICE TRAINING

In California, workshops are being offered wherever possible in coordination with district curriculum offices, by regional trainers. Newsletters will notify teachers of workshop dates and locations.

In Massachusetts, in-service training is being coordinated by Professors Robert Dillman and Robert Boutilier of Bridgewater State College. They and eight other faculty members in other parts of the state will be offering eighty 3-hour and six day-long workshops this spring and next fall. In addition, Drs. Dillman and Boutilier have agreed to man a hotline to provide aid when you need it. If you have a question about the ENERGY 80 materials or in-service training, call 800-342-3794 and leave a message for the "ENERGY 80 CENTER" along with your name, school, community and phone number (including area code) . Dr. Dillman or Dr. Boutilier will return your call within 48 hours. In the unlikely event they cannot help you, they will refer the question to our office and we will see what we can do. A spring and fall newsletter will also be sent to your school.

In Oklahoma, in-service training is being coordinated by the Oklahoma Council on Economic Education. In particular, we refer you to BUSED 5660 Workshop offered by the Center for Economic Education at Oklahoma State University. For more information, contact the Council's Executive Vice-President, Professor Clayton Millington at Business Building Room 112; Stillwater, Oklahoma 74074 (405-624-5204x).

In Texas, plans are still under discussion at the time we go to press; specifics will be announced in a newsletter in the Spring of 1981. Guiding the planning are Terry Brandt and Caroline Penn of the Harris County Department of Education and the members of the Editorial Advisory Board for Texas, some twenty-five district science and social studies curriculum directors.

As you've probably noted, preparations for in-service are in a more advanced stage in Massachusetts than other states. This is in part due to the early assistance of the Massachusetts Business Roundtable, which made it possible to get down to specifics at an earlier date. We expect that by the fall of 1981 each of the listed states will have different but equally comprehensive provisions for in-service.

John Lord
Editor
Energy 80

A Teacher's Guide
to the
Energy 80
student booklet

Enterprise for Education, Inc.

Both as a teaching guide and an annual publication, this publication falls outside the scope of the Library of Congress Cataloging in Publication Program. We suggest the following card entry:

Teacher's Guide to the "Energy 80" Student Booklet, A

(An element of the Energy 80 program.)

1. Power Resources---Study and teaching.
2. Energy policy---Study and teaching---United States.
I. Energy 80.

HD9502.U5T 333.7

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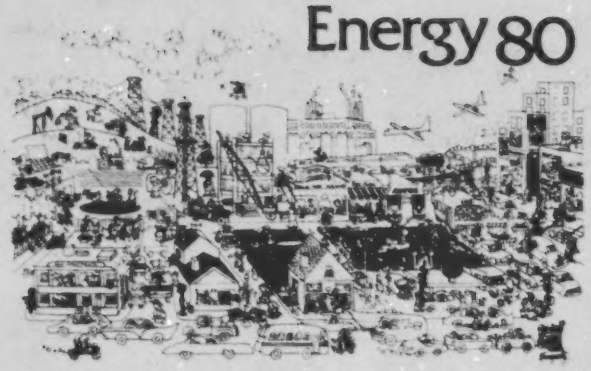

With this teacher's guide you should have received at least 30 copies of a student booklet. This guide suggests ways of using the booklet, and also introduces the Energy 80 program.

GRADE LEVEL = JUNIOR HIGH/MIDDLE SCHOOL

Teachers have also indicated the materials were suitable for use at higher grade levels, and even, to a lesser extent, the upper elementary grades.

SUBJECT AREA = SOCIAL STUDIES, SCIENCE

The most productive way of using the booklet depends upon your class and the time you wish to devote to the topic. Notice that each spread (two facing pages) in the booklet treats a separate topic. There are 16 spreads in all. The suggestions which follow are arranged spread by spread. At the end of this book is an appendix containing selected lessons and worksheets from the balance of the program.

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PROTECTING PARENTS' PRIVACY

The more closely energy education relates to the individual student's situation, the more effective it is. Collecting data about his or her own consumption of energy is one of the most fruitful things a student can do.

However, many families are extremely sensitive about sharing data on their family's energy purchases with other people. They have every right to their privacy in this matter. It can be very helpful if, before beginning any activity that requires the student to collect data on family energy consumption, you send a note home to the parents explaining the reason for the unit and stating that, while the student is required to do the homework, he or she is not required to share the information with you or the class. If you are concerned about your students not doing work that does not have to be turned in, consider asking parents to check that the data has been collected, providing them with a slip to sign that states they have done so.

Most of the discussions of the two-page readings in the student booklet contain the following items:

Vocabulary

You may wish to introduce some of these words prior to assigning the reading.

Resources

These brief references are especially intended to call attention to low-cost, no-cost materials.

Evaluation

A mini-quiz is provided for making a quick check of what students have learned from each spread. To make it easier for teachers who are not familiar with the subject matter to judge the correctness of answers, the quizzes mostly consist of simple recall questions. If you're knowledgeable on the topic, you will be able to think of higher level questions that would better evaluate the full range of student learning.

Also included are true and false questions. These are not intended for evaluation, but as a means of stimulating an oral class review at the close of periods.

ENERGY SOURCES (primarily for science classes)

Day	Purpose/ Activities in class	Assignment for next day
	The first week is devoted to establishing the idea of energy flow: we don't make or use up energy, we catch it on the fly.	
1	Focus student attention on topic Relate to student's own experience fill out worksheet, booklet p 1 note to parents if home energy data to be collected	read booklet pp 2&3
2	Review forms of energy Establish that energy flows from form to form, is not made discuss booklet pp 2&3 activity: convert energy from one form to another, such as lightbulb, appendix p 1-5	read booklet pp 4&5 complete matrix, appendix p 1-3
3	Reinforce flow concept with natural example, if sunny activity: water cycle demonstration, appendix p 2-3	read booklet pp 6&7
OR		
3	Another conversion activity, e.g., appendix p 1-7 or 1-11	
4	Reinforce flow concept with natural example activity: wind box, appendix p 2-9	read booklet pp 8&9
5	Natural example of stored energy: food Introduce fuel concept activity: calorimeter, appendix p 2-15	read booklet pp 10&11

ENERGY SOURCES (primarily for science classes)

Day	Purpose/ Activities in class	Assignment for next day
	In the second week, examine energy sources used in the economy.	
6	Establish usefulness of fuels to people see lesson app p 3-3	read booklet pp 12&13 worksheet app p 3-5
7	Coal Characteristics / early development reading, app p 3-18 activity in lesson app p 3-7 chart, booklet p 29 Establish present uses, chart booklet pp 22&23 Future use? discuss assigned reading	read booklet pp 14&15
8	Petroleum & Natural Gas Examine contribution, booklet pp 22 & 23 Discuss origin, occurence, extraction	read booklet pp 16&17
9	Nuclear Examine nuclear contribution on chart booklet pp 22&23 Examine mechanism, lesson on app p 4-11	read booklet pp 18&19
10	Renewables Examine need Examine operation of active & passive emphasizing absorption, transfer, storage ********* Evaluation Students re-evaluate booklet p 1 responses Test	None.

EFFICIENCY (primarily for science classes)

Day	Purpose/ Activities in class	Assignment for next day
1	Review idea of energy conversion, do a conversion such as app pp 1-5, 1-7, or 1-11	read booklet pp 2 through 5
2	Prepare for efficiency investigation by measuring two forms of energy, see lesson app p 1-69	
3	Establish concept of efficiency through an investigation measuring efficiency, see lesson titled First-Law Efficiency, app. p 1-75	
4	Make practical application of efficiency concept, see lesson appendix p 1-83	worksheet in lesson
5	Use lesson titled System Efficiency, app p 1-89	read booklet pp 20 through 23

In the second week, shift focus to the role of efficiency in the economy and in possibilities for conservation.

6	Discuss "waste energy" in economy use flow chart booklet pp 22&23 use worksheets on efficiency in guide.	Franklin Stove, app p 6-7 read booklet pp 28&29
7	Investigate opportunities for increasing efficiency at home and in school, emphasis on use of waste heat, control of heat	worksheet, app p 8-6
8	Continue home/school investigation. emphasis on habits routines that decrease efficiency	worksheet, 8-4 read booklet p 32
9	Efficiency in local industrial process: research in advance, get speaker if possible	read booklet pp 30&31
10	Evaluate role of efficiency in maintaining or improving quality of life while decreasing energy consumption	none

HISTORICAL PERSPECTIVE (primarily social studies classes)

Day	Purpose/ Activities in class	Assignment for next day

As underlying questions to guide your study of U.S energy history, consider the following:
How has the abundance of America's resources influenced her people's use of energy? How has scarcity of labor affected our use of energy?
Is there a characteristic American attitude toward technical innovation and change, and if so, how was this affected our energy history?

In the first week, establish why we are studying this, some basic principles of energy use, and look at changes in energy use in the pre-fossil fuel period.

1	Focus on history as a means of helping us understand the present today: talk of crisis, changes foreseen how is today unique? how like the past? Energy use in earliest colonial America examine in class & discuss Smith, app p 6-3 identify food, wood, gunpowder as energy sources	read booklet pp 2 through 5
2	Verify that students understand energy cannot be made, that there are limited number of sources. May wish to use booklet pp 2223 in discussion.	read Franklin, app p 6-7
3	What types of causes have lead to changes in the use of energy in the past? deduce wood fuel supply situation from Franklin what is Franklin's response to problem?	read Twain, app p 6-23
4	What changes are evident from Twain? the Coal Age, on to industrialization	read Wilder: Threshing, appendix pp 6-43 to 6-47
5	What has been the role of labor-saving machinery? why do attitudes to labor-saving (automation) differ scarcity of labor as a cause of American interest in labor-saving machinery	read booklet pp 12&13

HISTORICAL PERSPECTIVE (primarily social studies classes)

Day	Purpose/ Activities in class	Assignment for next day
	In the second week, we shift the focus to the various impacts of the fossil fuels.	
6	Establish time line for world coal use for use of coal in U.S.	Royal Proclamation, app p 3- read booklet pp 14&15
7	Establish time line for oil and gas use in U.S. Relate petroleum to rise of automobile How has automobile affected our society?	interview elderly person on energy used in home, work, transportation in their childhood
8	Relate rise of petroleum and gas to ease of use compared to coal	read booklet pp 20&21 worksheets, app pp 3-17 to 19
9	Review energy transitions in U.S. History use bar chart, booklet p 20&21	read booklet pp 22&23, 26&27
10	Energy and America's relation with rest of the world	readings in current local newspaper

CONSERVATION (primarily social studies)

Day	Purpose/ Activities in Class	Assignment for next day
	The first week is devoted to establishing the reasons for our energy situation and the chief technical opportunity, increased efficiency.	
1	Establish energy situation: precarious supply review oil import graph, booklet pp 14&15 review global sources, map booklet pp 26&27 review use of petroleum, chart booklet pp 22&23	read booklet pp 14 & 15, 26 & 27
2	Establish energy situation: in long run, fossil fuel depletion use lesson Depletion of Non-Renewable Resources, appendix p 3-37	read booklet pp 3 through 6 worksheet app p 8-2
3	Review basic physics of energy: energy flows through conversion after conversion, but can't be made;most of our mechanical energy now comes from heat; we can't get all the energy out of a conversion in the form we want.	worksheet app p 1-83
4	Learn to read utility meters see lesson in app pp 1-39	worksheets
5	Learn to understand utility bill see lesson app p 1-49	worksheets which you must make

CONSERVATION (primarily social studies)

Day	Purpose/ Activities in Class	Assignment for next day
	The second week is devoted to examining how energy can be conserved and what the effects of conservation might be.	
6	Improving use of heat in household	worksheet app p 8-7
7	Habits examine use of energy in school	worksheet app p 8-13
8	Efficient use of automobiles	read booklet p 32
9	Conservation in industry choose a local industry and examine its energy use arrange a telephone call to a plant official	read booklet pp 30&31
10	Examining whether we feel we must use more energy in order to have a good life.	none

MESSAGE; WORKPAGE

Reading Level: varies by state because of differing messages

Objectives

The student realizes that responsible people take the energy problem seriously.

The student assesses his or her present knowledge of certain aspects of the energy situation.

Background Information

Message

The message from the Governor (in California, the senior United States Senator) is provided as a means of conveying to students that knowledgeable people believe the energy situation is a serious problem.

Activities and Discussion Topics

1. Read the Governor's message. What particular aspects of the energy situation seem to be of most concern to him?

2. Might the situation in our state differ significantly from that in some other state? For what reasons?

3. Ask students to fill in the workpage on page one. If you must save the booklets for reuse next year, students can write the answers on a separate sheet of paper. You may choose to assign this as homework or to do it in class. The students themselves should be given a chance to correct their answers after they have used the materials, at the end of the unit. For your information only, here are the answers to the last set of questions:

Most energy last year = petroleum (5)
Most important in generating electricity = coal (1)
Greatest domestic production = natural gas (3)
Provided most U.S. energy in 1940 = coal (1)
Almost half comes from other countries = petroleum (5)
Provides most transportation energy = petroleum (5)
Comes from sunlight = 1, 2, 3, 5
Most important home heating fuel = depends on your location. Consult state or city energy office or utility if answer is not obvious to you.
Energy sources for electricity = phone the public affairs department of your local utility and request this information.

IN ALL THE UNIVERSE THERE IS ONLY...(pages 2 & 3)

Reading Level (by Fry count): 9th grade

Objectives

The student recognizes that there are different forms of energy.

The student recognizes that we cannot make or destroy energy.

The student is aware that energy can be converted from one form to another, and that almost every human use of energy involves such a conversion.

With the use of supplementary lessons:

The student knows energy can be measured and can make some types of energy measurements, including temperature measurements.

The student is able to read utility meters and understand the form of utility bill used in his or her area.

The student recognizes that there are common patterns in household energy usage.

Background Information

Some students may raise religious objections to the headline. Emphasize that in this context we are only talking about the physical universe, things we can measure. In other frames of reference, other things would be important.

Most junior high school students will have learned about forms of energy in previous grades, so that aspect of this lesson is largely review. Often, however, they have not recognized that all uses of energy involve conversions.

Forms of Energy

The important point here is for students to realize that energy does take different forms and to be able to recognize some common ones. The conventional list of forms of energy used here is just a convenience. There are many other forms of energy, such as the elastic energy in a stretched rubber band, the surface energy of solids and liquids, the binding energy of the nucleus, and so forth. Though heat is commonly given as a separate form of energy, it is really energy of motion.

Incidentally, although it is common everyday usage to refer to the "heat stored in a body," this is meaningless from the physicist's point of view.

Heat, like work, is energy in transit. The temperature of a body can be raised by methods other than the transfer of heat; for example, by compressing a gas. For this reason, physicists prefer to lump everything together and refer to the "internal energy of a system."

Activities and Discussion Topics

Elicit the names of some forms of energy from students. Point out that some forms of energy are energy in transit, like heat and mechanical energy (work), while others are stored energy, like potential energy of the water at the top of a waterfall or the chemical energy in a battery.

On appendix page 1-3 is a worksheet which asks students to fill in various means of conversion. Students should not be expected to be able to fill all the cells of the matrix.

Then discuss the question raised in the text. Here are the answers:

Motorcyclist: chemical energy in gasoline to heat to motion; motion to electricity (due to the generator) to light and heat.

Woman in robe: hairdryer, electricity to heat and motion; toaster, electricity to heat and light, motion is stored as potential energy in spring, then converted to motion again; coffee pot, electricity to heat, heat to motion (of the coffee); radio, electricity to heat and motion (the sound).

Race Official: chemical energy in the cartridge to heat to motion (of the gas coming out of the barrel).

Cyclist: chemical energy of food to motion; in the generator, motion to electricity, electricity to light and heat in the headlight.

Woman sharpening knife: chemical energy (from her food) to motion to heat.

Brownie with magnifying glass: light to heat.

Boy Scout: chemical energy (from his food) to motion to heat.

Diogenes: chemical energy of lantern fuel to heat and light; in the television set, electrical energy to heat, light, and motion (the sound).

Man with flashlight: chemical energy in battery to electricity to light.

Further Concepts

This lesson can begin a set of lessons developing the following sequence of concepts:

Energy exists in different forms.
Energy is converted from one form to another. This is perhaps best taught through hands-on experiences, see samples in appendix pp 1-5, 1-7, 1-11. These lead to an understanding of:
Energy is not created or destroyed.
Energy can be measured.
Heat is the easiest form for students to measure. See appendix pp 1-17 through 1-31.

Electricity. A lesson using rating plates on household appliances to introduce the units in which electricity is measured is included in the appendix on p 1-33. This should be followed by lessons on volts and amps, which are not provided because they are easily constructed.

Measurements of household energy consumption. See appendix pp 1-39 to 1-67.

Begin keeping personal consumption records for later analysis.

Measurements of energy in different forms can be equivalent. See lesson beginning on appendix p 1-69.

This leads to the subject of efficiency, treated in the next spread.

We believe these additional lessons are worth the effort because until students can compare amounts of energy, it is very difficult to say anything meaningful about energy use and production.

Mini-Quiz

1. Name one kind of stored energy. [any form except heat, work, light or electricity, for example chemical energy or potential energy]

2. Name any way of changing chemical energy to light. [combustion]

3. What kind of energy goes into an electric motor? What kind comes out? [electrical energy, electricity; energy of motion, motion, or kinetic energy]

4. What kind of energy does a car run on? [chemical energy]

5. What kind of energy do you run on? [chemical energy]

6. What kind of energy is present in natural gas? [chemical energy]

7. What kind of energy does a speeding bullet have? [energy of motion, kinetic energy]

8. Name a way of changing chemical energy to heat. [Burning or combustion is the usual answer; there are others which would be correct.]

9. In friction, what form of energy is converted to what? [motion to heat]

10. What is the name of a device for changing electricity to motion? [electric motor, or anything incorporating an electric motor]

True or False?

Energy is destroyed when you blow out a candle. [F]

As a candle burns, energy is destroyed. [F]

Someday, someone may succeed in building an engine that will move cars and not need any fuel or outside energy source. [F]

ENERGY...RULES OF THE GAME (pages 4 & 5)

Reading Level (by Fry count): 8th grade

Objectives

Students expect that in any practical energy conversion, part of the energy will be converted to heat.

Students describe efficiency as way of describing what percentage of the energy we put into a conversion will come out in the form we want.

Students realize that devices doing similiar jobs may have very different efficiencies.

Students recognize that there are theoretical limits on the efficiencies of various conversions.

Students appreciate the importance of looking at as much of an energy flow as possible, not just at one component.

Students recognize the economic importance of the conversion of heat to work.

Vocabulary

efficiency
system efficiency heat engine

Resources

The Project for an Energy-Enriched Curriculum (NSTA) has prepared a module for grades 11-12 titled There's Enough Energy, So What's the Problem, which is available free from DOE/TIC, P.O. Box 62; Oak Ridge, Tennessee 37830. Energy and Order, by Mark Dewitt and Paul Terry also treats thermodynamics in a teachable fashion (San Francisco: Friends of the Earth, 1976).

Background Information

System Efficiency

Notice that the efficiency of a system is found by multiplying together the efficiencies of all the components.

The numbers chosen are representative of commonly encountered appliances and utility systems. One could find gas heaters that were more efficient than 46%, and gas utilities with much higher losses.

Sometimes the efficiency of an electric water heater is given as 99%. (Theoretically, electricity can be converted to heat at an efficiency of 100%.) The 79% figure comes from considering the whole system within the house, from fuse box to heat at the tap, not just the conversion efficiency of the heating elements.

Does the fact that the gas system shown is more efficient than the electrical system shown lead to the conclusion that a homeowner is better off heating water with gas than with electricity? NO. We need to look at the homeowner's particular system.

First, what source of energy was used to generate the electricity? For the sake of the comparision, in the example the electricity was generated by burning natural gas. Only about 15% of U.S. electricity is being produced from gas. In an area where electricity is generated in long-established hydroelectric plants, it may be more sensible to use the renewable electricity for water heating and save the gas for other uses such as very high temperature heating. Similiarly, nuclear fission can only be used for home water heating when it is distributed in the form of electricity. If it is thought desirable to save gas by substituting nuclear where possible, then it would make sense to heat home water with electricity rather than gas.

Secondly, how is the electricity used? In the example, the electricity was converted to heat as it is in an electric stove: by running it through a resistance element. Most electric water heaters work this way. It is not the most efficient way of heating water with electricity. It would be far better to take advantage of the fact that electricity can be easily converted to work, another high-quality energy form. An electric motor running a heat pump could deliver an amount of heat (taken from groundwater or the air) far greater than the heat equivalent of the electricity consumed. Substituting such an electric water heater for the electric heater in the example would produce a system which would have a higher system efficiency than the gas water heater system has. (There are also more efficient gas heaters.) A similar system preheats water using the heat exhausted by air conditioners, and again, the heat is made available by the work done by an electric motor. Both heat pump water heaters and air conditioner water heaters are practical systems presently in use.

Lastly, you use what you've got. If a mile of gas main would have to be laid just for you to use gas to heat water, your energy savings would never approach the energy needed to make and install the pipe.

How can a person decide questions like which is best in a particular situation, the gas water heater or the electric water heater? Though not infallible, cost is a pretty good guide. The method with the lowest lifetime cost is likely to be the one that uses the least energy. Deciding on the basis of cost also has the advantage of taking into account indirect energy consumption, for example to manufacture and deliver the heaters.

Heat Engines

In all heat engines, heat flows from a high temperature reservoir (commonly called the source) to a low temperature reservoir (the sink). Part of the heat flow is converted to work. In the early 1800s, a French engineer named Sadi Carnot perceived that no matter how this was done, there was no way of changing all of the heat energy to work, and the percentage that could be changed was determined by the difference in temperature of the source and sink. Later scientists found a mathematical expression for the theoretical efficiency:

$$\text{efficiency} = 1 - \frac{\text{temperature of sink in degrees Kelvin}}{\text{temperature of source in degrees Kelvin}}$$

Zero degrees Kelvin (absolute zero), which is about -273°C, is as cold as it gets. Celsius temperatures can be converted to Kelvin by adding 273.

Note that the theoretical efficiency can never be achieved in practice, because of friction and other inevitable losses. No gasoline engine has an actual efficiency anywhere near 60%.

The nearer the thermal efficiency of any device gets to the theoretical limit, the harder it is to make further improvements, whether we are talking of power plants or locomotives.

Activities and Discussion Questions

Efficiency and Waste Heat

The reading gives the example of a fan getting warm. Ask students if they can think of other examples of energy uses in which unwanted heat is produced. In the classroom? (heat from lights?) In the car or bus on the way to school? (heat from engine) In almost any energy conversion, waste heat will be produced.

Can they think of anything we could use the waste heat for?

For further information on this topic, see the lesson First-Law Efficiency on appendix p 1-75. The succeeding lesson, Incandescent v. Fluorescent Efficiency, provides a practical application of the principle.

System Efficiency

Please refer to the lesson plan, Systems Efficiency, appendix p 1-89 for overhead transparency masters and other information on this topic.

Heat Engine

List some different heat engines. What produces the heat? Where does the heat go? Can you think of any devices that produce mechanical energy that are not heat engines.

Consider using the worksheet on appendix p 3-29.

Mini-Quiz

1. In all conversions of energy from one form to another, part of the energy is converted to what form of energy? [Heat]

2. A number which compares the amount of energy we get out of an energy conversion in the form we wanted, with the amount of energy we put in, is called what? [efficiency]

3. Which is more efficient, an incandescent light bulb or a fluorescent light? [fluorescent]

4. Two electric lights use the same amount of electricity, but light A gives more light than light B does. Which light is more efficient? [light A]

5. Two electric fans produce exactly the same air movement. Fan B uses less electricity than fan A. Which fan is more efficient? [fan B]

6. The people who design turbines, like jet engines, are making a great effort to find new materials for the turbine blades. They are trying to use materials like ceramics, because metals lose their strength at the temperatures at which the engineers would like the engines to operate. But the ceramics are brittle and keep breaking. Why are the engineers wasting so much time trying to get the engine to run at higher temperatures? [to increase the efficiency of the turbines]

7. What do we call a machine that changes heat to work? [a heat engine]

8. If we want to find the theoretical efficiency of a particular heat engine, what will we have to measure? [temperature]

9. Name two different kinds of heat engines. [steam engines, gas turbines, internal combustion engines, etc]

10. If we follow the loss of energy as it flows through a series of different machines, we are looking at what kind of efficiency? [system efficiency]

True or False?

Diesel locomotives are not as efficient as the last of the steam locomotives were. [F]

A steam turbine is a kind of heat engine. [T]

An automobile converts about 80% of the energy in the gasoline into forward motion. [F]

Photosynthesis is a very efficient process compared to an electrical powerplant. [F]

Anything with an efficiency of less than 50% is no good. [F]

OUR SUN...ENERGY SUPERSTAR (pages 6 & 7)

Reading Level (by Fry count): 7th grade

Objectives

Students recognize that all major energy flows on earth begin with sunlight, in particular the water cycle, wind energy, and the energy of living things.

Students recognize that materials are not used up in the wind, water, and photosynthesis-respiration cycles.

Students realize that an enormous quantity of energy reaches the earth in the form of sunlight.

Students recognize that sunlight is a diffuse energy source, in contrast to concentrated sources like fossil fuels.

Vocabulary

photosynthesis
wind cycle
water cycle

Resources

Consult "Resources" on page 23.

Background Information

The headline refers to the sun as an "energy superstar," which it is to earthlings. However, as stars go, the sun is a very ordinary, medium-sized star.

The earth is so small and so far from the sun that only about a billionth of the energy the sun radiates into space is intercepted by the earth's outer atmosphere. Of that intercepted energy, it is estimated that about:

30% is reflected away as visible and ultraviolet light (Earthshine, which we sometimes notice as illumination of the darkened portion of a new moon.)

47% is absorbed in the atmosphere and reemitted, mostly as infrared radiation

23% is associated with evaporation and precipitation (the water cycle)

0.215% is associated with winds, waves, and ocean currents

0.023% is captured by photosynthesis

As these figures show, by far the greatest part of the solar energy that reaches the earth's surface is used to evaporate water. (Some have said Earth should have been named Water.) This process provides most of the energy evident in weather. The energy of violent storms is mind-boggling; it has been estimated that an ordinary thunderstorm involves 20,000,000,000 Btu, while the energy released in a single day by a mature, moderately-sized hurricane is about 50 quadrillion Btu, about the same as the entire amount of energy used in the U.S. economy in 1970.

Note that horsepower and watts measure the rate at which energy is being supplied or converted. They do not measure an amount of energy. By saying how long the energy was being supplied at that rate, we could specify an amount of energy. Horsepower-hours and watt-hours do measure a quantity of energy.

Wind

Wind is a large-scale example of a convection current, like boiling water in a pot or the clouds of cold cream in hot coffee.

Different parts of the earth receive different amounts of light energy per square meter, because the sun is more directly overhead in the tropics than the polar regions. A time-proven demonstration of this uses a dozen sharp wood pencils held together with rubber bands. The pencils represent rays of light. Hold them perpendicular to a sheet of paper and jiggle them slightly, so that each pencil makes a mark. This represents the tropics. Now do the same for the polar regions, letting the pencils meet the paper at a pronounced slant. Which piece of paper has more marks per square inch? The one with the sun overhead.

The resulting unequal heating of the earth causes the convection currents we call winds. The air rises over warm areas and sinks over cold. Winds must move in a circle (a convection cell). Therefore the direction of the winds at ground level can differ from that at high altitudes.

This simple picture is changed by many factors, principally the earth's rotation. Most geography and earth science texts explain these complications.

Photosynthesis

Like the wind and water cycle, photosynthesis is part of a cycle. It has been estimated that every 300 years an amount of carbon equal to the entire stock tied up in living things passes through the cycle; it takes 2000 years for the stock of oxygen to be recycled. It is extremely likely that you have breathed some of the same molecules of air that Julius Caesar did. Photosynthesis is considered in more detail in the next spread.

Water Cycle

Note that when water evaporates, energy is stored in the vapor. When the vapor condenses, heat is released.

The water cycle is an example of a natural process by which the diffuse energy of sunlight is concentrated. Collecting the potential energy raindrop by raindrop would be impossible. However, thanks to rivulets, streams, and rivers, large quantities of water are assembled at points well above sea level. At such sites it is feasible to erect mills and hydroelectric plants to exploit the water's potential energy.

What Kinds of Energy on Earth Don't Come from the Sun?

Very few, namely:

Geothermal energy, which mostly comes from the decay of naturally-occurring radioactive elements in the earth.

Tidal energy, which comes from the earth's kinetic energy as it spins on its axis and moves in its orbit. As this energy is converted to heat over the eons, the day gets longer by 0.001 seconds per century.

Nuclear energy, which comes from human activities that convert mass to energy.

Activities and Discussion Topics

Enormous Amount and Diffuseness of Energy in the Sunlight Received
Let's do some back-of-the-envelope estimating on the chalkboard.

1. The United States has an area of about 3,631,407 square miles, which is about 9.5 trillion square meters. (1 square mile = 2,589,988 square meters) If one square meter is receiving light energy at a rate equivalent to one horsepower at noon, how many horsepower is the whole United States receiving? If one square meter is receiving light energy at a rate equivalent to 600 watts, how many watts is the whole United States receiving?

2. If a square meter received one horsepower, and assuming all the energy could be converted to work (100% conversion efficiency), how many horsepower would a solar-powered car be on a bright sunny day?. [ANS: If a car covers six square meters, six horsepower.]

> So, sunlight is a diffuse energy source compared to the concentrated ones we are accustomed to thinking of, but taken altogether the quantity available is enormous (and, in the long term, it is ultra-reliable).

Wind: an example of the power of sunlight

3. What use did people make of wind in pre-fossil fuel days. (Sailing)
4. Have you ever seen a windmill? What work did it do?

Please see the lesson titled The Wind Cycle on appendix p 2-3.

Water

Have students make a diagram of the flow of water in the water cycle. Then try to add energy to it.

Please see the lesson titled The Water Cycle on appendix p 2-7.

Mini-Quiz

1. About how many watts of sunlight fall on a square yard at noon? [500 watts]

2. What is the name of the process by which plants store light energy as food? [photosynthesis]

3. At the equator, would you expect air to be rising or falling? [rising]

4. It is too bright in my room. I pull dark shades over the window. What form of energy is the light converted to? [heat energy]

5. What form of energy is present in wind? [energy of motion, kinetic energy]

6. Before 1800, what source provided the energy for travel between Europe and America? [wind]

7. When a wet towel dries, what has become of the water? [It has turned to water vapor.]

8. What is the name of the process by which water vapor becomes liquid water again? [condensation]

9. A farmer is getting electrical energy from his wind-powered generator. What did this energy look like when it first reached Earth? [sunlight]

10. The energy animals use to move comes from their food. Before it was food, what kind of energy was it? [light]

True or False?

The sun will not go out for billions of years. [T]

Some objects do not absorb any light at all. [F]

In a few million more years, all the rain will have fallen into the oceans and there will be no more rain. [F]

[OUR SUN] ...PROVIDES FOOD ENERGY (pages 8 & 9)

Reading Level (by Fry count): 8th grade

Objectives

Students recognize that the energy required for all life activities comes from the sun.

Students recognize that all materials in the photosynthesis-respiration cycle are recycled.

Students are aware of additional energy inputs in the U.S. food system.

Resources

An excellent compendium of lessons on this topic is "Energy, Food, and You," available in either an elementary or secondary edition (specify) for a $5 check payable to Environmental Education/E.S.D. 189 from Shoreline School District Admin. Bldg.; NE 158th and 20th Avenue NE; Seattle, WA 98155; attn Tony Angell.

Background Information

How Plants Trap Energy

Note that the oxygen given off comes from the water molecule, not from the carbon dioxide molecule. Scientists can demonstrate this using radioactive tracer isotopes of oxygen.

The text emphasizes photosynthesis in leaves. However, of the estimated 200 billion tons of carbon annually incorporated in living things as a result of photosynthesis, only 20 is fixed on land, and 180 in the oceans, mostly by plants that do not have leaves, the one-celled algae.

A minor exception makes it incorrect to state that all photosynthesis takes place in green plants. There are a few odd bacteria which carry on photosynthesis.

The formula shown is a summing up of the results of photosynthesis, not a step-by-step description of that complex process. Such descriptions are available in high school texts or an excellent series of articles in Scientific American.

Passing Food Energy Along

Here the word chain is used, which can perhaps describe one meal. However, because animals may eat a variety of plants and animals, the phrase "food network" is more accurate.

The loss of 90% of the energy at each step in the chain is typical, but the percentage varies.

Actually, people do not need proteins but the amino acids from which the proteins are made. There are eight amino acids people must obtain from their food; all the others can be synthesized by the human body. For example, wheat by itself is poor in the amino acid lysine, but wheat can be

can be eaten with other plant foods high in lysine, like beans. Thus it is possible for people to get all the proteins they need without resort to meat. But it isn't easy.

Cashing in Your Chips

Biologists give the name respiration to the process of obtaining energy from food. (Breathing they call external respiration.)

Note that respiration is just as essential to plants as it is to animals.

Takes More Than Sunlight to Set the Table

The amount of energy needed to produce a calorie of food energy varies greatly. In general, the higher up the food chain you go, the more energy required per calorie of food.

Activities and Discussion Topics

Review the Photosynthesis-Respiration Process

On the chalkboard, review the inputs and outputs.

Balance the equations by counting the number of atoms of each element in what we start with and what we end up with. Verify that no materials are lost.

Students can make a crude measurement of the energy content of food. On appendix p 2-15 is a lesson plan, Measuring Food Energy, including an activity in which students make and use a crude calorimeter.

Food Chains

A worksheet that helps students investigate their own food chain is provided on appendix p 2-19.

Energy Use in the Food System

A worksheet which can serve as a brief introduction to one aspect of energy use in the food system, transportation, is provided on appendix p 2-20.

Mini-Quiz

1. Name the three chemical elements that are recycled in the photosynthesis-respiration cycle. [carbon, oxygen, hydrogen]

2. Sugars and starches are made of these elements. That is why sugars and starches are called what? [carbohydrates]

3. What form of energy goes into the energy conversion we call photosynthesis? [light energy]

4. What is the name of the gas we give off as a result of our use of energy? [carbon dioxide].

5. What is the name of the gas plants give off as a result of photosynthesis? [oxygen]

6. As energy is passed along a food chain, about how much is lost at every step? [90%]

7. What is the name of the gas plants take for photosynthesis? [carbon dioxide]

8. What is the name of the unit used to measure food energy? [Calorie or kilocalorie]

9. What are the biggest sources of the energy used in the U.S. food system? [petroleum and natural gas]

10. When you eat a 1000 Calorie meal, about how may Calories of energy (other than food energy) were needed to put that meal on your plate? [100,000 Calories]

True or False?

Each year carbon is used up in photosynthesis and so eventually the world will run out of carbon. [F]

If there were no plants, only the meat-eating animals could survive. [F]

The energy you use to ride a bike came from a star. [T]

There is no limit to the amount of food energy you can obtain from an acre, provided you can put on as much fertilizer as you want. [F]

People are at the bottom of their food chain. [F]

FOSSIL FUELS... SUPER-LONG-STORED-UP FOOD ENERGY (pages 10 & 11)

Reading Level (by Fry count): 7th grade

Objectives

Students recognize that the energy of fossil fuels came from sunlight.

Students recognize that the fossil fuels were formed over eons through geological processes.

Students recognize that coal consists principally of carbon, and that there are different types of coal.

Vocabulary

peat
lignite
bituminous coal
anthracite
sediments
sedimentary rock
crude oil

Resources

Nowadays, most students have never seen coal or oil. Perhaps you can borrow some from the earth science teacher; suppliers like Ward's sell prepackaged kits of energy resource specimens. The National Coal Association (Coal Building, Washington DC 20036) provides a free pamphlet "Buried Sunshine" that has blister-packed to it some thumbnail-sized specimens of peat, lignite, bituminous coal and anthracite. These are better than nothing.

Background Information

Lately, the possibility that some natural gas is a remnant of the primordial methane present at the earth's formation (and is not biological in origin) has been discussed in the press. Most geologists appear to be skeptical.

Some school science collections include coal specimens which display the imprint of fern leaves. If you can borrow one of these, it makes a most convincing demonstration of the origin of coal.

Activities and Discussion Topics

1. How do you explain the fact that coal occurs in seams, or layers?

2. From your knowledge about how oil is formed, what kinds of clues would you look for if you were searching for oil? What kinds of rocks would you look for? Could looking for fossils help you find oil? What kind of fossils would you look for?

3. Are the fossil fuels formed quickly or slowly? Do you think any are being formed today? Which do you guess is faster, the rate of formation or the rate at which we are extracting them?

Mini-Quiz

1. Coal is mostly made of what chemical element? [carbon]

2. The energy we get from coal originally came from what kind of energy? [light, sunlight]

3. What is the name given to materials like sand and clay when they are deposited at the bottom of lakes and oceans? [sediments]

4. What do we call plant remains when they are in the first stage of changing to coal? [peat]

5. What is the name of the kind of rocks oil is found in? [sedimentary]

6. What kept the plants that turned into coal from rotting after they died? [Being covered with water.]

7. Why is most anthracite found in mountainous areas? [because the anthracite is formed by the heat and pressure that is part of mountain building]

8. How long ago did most of the plants that became coal grow? [300 million years ago]

9. What size are the holes underground in which oil and gas is found? [tiny]

10. Where did the plants and animals that became petroleum live? [in the ocean]

True or False?

As time passes, due to heat and pressure the layer of plant materials that will become coal grows thicker and thicker. [F]

Crude oil is a mixture of different substances. [T]

The layer of plant remains that was changed to coal might have been 20 times thicker than the resulting coal seam. [T]

We are absolutely certain how oil is formed. [F]

COAL: THE ONCE AND FUTURE KING? (pages 12 & 13)

Reading Level (by Fry count): 8th grade

Objectives

Students are aware that use of coal did not begin until the late Middle Ages.

Students recognize that exploitation of coal provided the energy for the development of industrialized societies.

Students identify coal as the dominant fuel in the U.S. from approximately 1880 to 1950.

Students are aware of some of the difficulties of extracting, transporting, and burning coal, and of controlling pollution, in comparision to other fossil fuels.

Students are aware of some air pollution control technologies.

Students know reserves of coal are greater than those of other fossil fuels, both domestically and worldwide.

Students know coal is the principal source of our electricity.

Vocabulary

[industrial Revolution*]
*Words or phrases not in the reading which you may wish to introduce in discussion.

Resources

The Project for an Energy-Enriched Curriculum (NSTA) has prepared a number of units exploring the outlook for coal, including "Western Coal, Boom or Bust" (grade 11), "Coal: Promise and Problems," (grades 6-9); "Making Decisions About Synfuels" (grade 11-12); "Fossil Fuels and the Greenhouse Effect" (grades 9-12). These are available free on request from the Dept of Energy Technical Information Center; PO Box 62; Oak Ridge, TN 37830. An adequate free-loan film, "Coal, the Other Energy," (15 minutes) gives a history and a survey of the present challenges, using a senior high vocabulary. Some other free resources have been listed by topic in the "Background" section.

Background Information

Edward I and England's Transition to Coal

On appendix p 3-9 is a reproducible copy of Edward's proclamation. Accompanying it is a suggested lesson in which students compare the burning of coal and wood using the most primitive form of open fire.

The Industrial Revolution

Today we are accustomed to technological revolutions taking only a few decades, like the transistor, computer, and jet airplane. But that was not the pace of change in the Industrial Revolution. Neither the steam engine nor the perfection of iron smelting with coke were rapid changes. Almost a hundred years passed from Darby's discovery of how to employ coal to make marketable iron until the use of coal to make iron was universal. The first practical steam engine was made by Savery in 1698, improved by Newcomen and by 1725 in widespread use pumping water from mines. It was not until the 1780's that Watt's improved engine began to be widely used for purposes other than pumping. Students may wish to discuss why innovation procedes more rapidly in some times and places than in others. (Perhaps consider: communications systems, availability of capital, attitude toward innovation, etc.)

Notice that in Britain coal and the steam engine contributed to each other's spread, somewhat as coal and the locomotive did in the United States. In its initial century, the steam engine was mostly used to pump, not to rotate a shaft. The pumping was needed to drain the coal mines. Without the steam engine, production of coal would have fallen drastically. Without coal, no supply of fuel adequate to the steam engine's demand would have been available.

A set of three films on the Industrial Revolution, which emphasize the role of English principles of liberty and the individual entrepreneur, is available on free-loan from Modern Talking Picture Service. The presentation is by scholars and the films do show the actual historical sites. If you intend doing a social studies unit on the Industrial Revolution, these might be worthwhile.

The Transition to Coal in the United States

One of the distinctive features of the energy history of the United States is that wood was the chief fuel for almost a hundred years longer than it was in other northern hemisphere industrial nations. Students can usually figure out why this was so. It may be important to point out that in some nations in the world wood and other plant matter is still the primary source of inanimate energy. In fact, Brazil is presently using charcoal for industrial purposes like steel-making (for which it is excellent).

In the eastern United States some of the old ironworks have been preserved, like the Saugus Ironworks in Massachusetts and Hopewell Village in Pennsylvania. This can be a meaningful field trip which demonstrates how, before the use of coal, such industries were dependent on surrounding forests.

Transition from Coal to Oil and Gas

See appendix p 3-15 for a lesson comparing the convenience of coal and gas in domestic use.

See appendix p 3-21 for a lesson on the development of the internal combustion engine, another factor which contributed to the replacement of coal by petroleum and natural gas.

Estimates of U.S Coal Resources

The United States is believed to have larger coal reserves than any other country, and they are relatively easily mineable.

In order to compare reserves of various domestic mineral energy resources, estimates of the physical quantities of reserves can be converted to the amount of heat that could be obtained from them. Here is how the total "heat reserve" breaks down:

coal	81.7%
petroleum	2.8%
natural gas	3.5%
natural gas liquids	0.6%
bitumins and shale oil	7.2%
uranium oxide*	4.2%

*Assuming a price no greater than $30 a ton and use in a light-water reactor.

Mining Coal

Underground coal mining is one of the most dangerous of all major occupations. In 1978, underground miners suffered 47.84 disabling injuries per million tons mined; surface miners, only 5.29. (The difference is not just in the amount of coal produced per person. Underground miners suffered 50.47 disabling injuries per million man-hours worked; surface miners, 16.55.) Increasingly stringent regulations have contributed to lowering the fatality rate from 1.95 fatalities per million man-hours in 1926-30, to approximately one fatality per Mm-h throughout the 1960s, to .28 fatalities per Mm-h in 1978.

Transporting Coal

In 1976, 64% of the coal was moved from the mine to the point of use by rail, 13% by motor vehicles, 12% was transported as electricity from generators located at the mine-mouth, and 10% by barge. (One percent was "other.")

Increased use of coal naturally means an increased need for transportation. "Unit trains," which carry only coal are one efficient means of moving coal, but the towns though which the railroads pass are fearful of the effects of what might become continual rail traffic. In some areas, the poor condition of the roads is blamed on their use by heavy coal trucks.

To transport coal by pipeline, it is ground very fine and mixed with water (or sometimes, oil) to form a slurry. One such pipeline has operated successfully. Much of the western coal is found in arid regions, which poses a problem for this technique.

Making synthetic liquid and gaseous fuels from coal is another solution to the transportation problem, and it is also a means of reducing the pollution created at the point where the fuel is burned. Making a fuel gas from coal is a two-century-old industry. Most of the utility gas was once synthetic, but it had half (or less) the heat energy per cubic foot of natural gas. However, gas with a heating value comparable to natural gas can be made.

New Ways of Burning Coal

In fluidized bed combustion, a constant stream of air is blown through a bed of finely-divided particles of burning coal.

Activities and Discussion Topics

1. The ancient Greeks and Romans made little use of coal. It was only towards the close of the middle ages that use of coal began to develop. Why might people prefer wood or charcoal to coal?

Try burning some, see appendix p 3-7. Besides a dislike of the smell, people were not aware that coal required a greater draft than wood and would not burn well in tried-and-true stove and furnace designs that worked well with wood.

2. What might have caused people to overcome their reluctance to burn coal? (Some scholars believe that England's transition to coal began in an energy crisis at the close of the Middle Ages. They believe deforestation had created a fuel wood shortage, and that this was an impetus to the use of coal.

3. When did use of coal in the U.S. get started?

4. Have you ever seen any coal?

5. How is transporting coal different from transporting oil or gas?

6. The student booklet mentions smoke in London. London became famous for its pea soup fogs. Today, those fogs are gone. Why? What happened in Pittsburgh?

Mini-Quiz

1. What was the name of the first practical machine able to change the energy in coal into mechanical energy, or work? [the steam engine]

2. In the 1700's, the English perfected a way of using coal to produce what metal? [iron]

3. What is the chief problem in burning coal? [pollution]

4. There are basically two types of coal mining. Which type is commonest in the western United States? [surface mining]

5. Which type is most dangerous? [underground mining]

6. Why type recovers more of the coal in the seam? [surface mining]

7. Name one pollutant found in coal. [sulfur]

8. Coal was first used as a substitute for what other fuel? [charcoal, give half credit for wood]

9. What is most of the coal burned in the U.S. today used for? [to generate electricity]

10. In what decade did coal overtake wood as America's chief energy source? [the 1880s]

True or False

At the time of the American Revolution coal was the major source of energy in America. (F)

Coal mined in the eastern United States usually contains more sulfur than coal mined in the western United States. (T)

We have much more coal than oil. (T)

Surface mining is more dangerous than underground mining. [F]

OIL AND GAS PRODUCTION & CONSUMPTION USA 1859-1980 (pp 14 & 15)

Reading Level (by Fry count): 8th grade

Objectives

Students recognize that oil and gas are depletable natural resources.

Students are aware that petroleum did not become a fuel until the 1860's.

Students are aware that our oil imports have increased greatly in the past decade.

Students recognize that the quantity of oil which can be produced is dependent on how much the oil is worth to us.

Background Information

What Was the Significance of Drake's Well?

Many notions about Drake's well are not correct.

Petroleum was bought and sold in America in the 1700's, long before Drake. It was obtained from seeps and by skimming pools and creeks, and often called Seneca oil. Because of the difficulty of obtaining it, only small quantities were traded, but by the 1850's, there was an oil refinery in Ontario, Canada, producing lamp oil from crude oil obtained from seeps and springs.

Drake and his co-workers did not invent the well-drilling technique. Most of the credit for that is due to David and Joseph Ruffner, who drilled a well for salt water in West Virginia in 1806.

Drake was not the first to strike oil. In 1814, a brine well being drilled at Rennix Springs, Kentucky, struck oil at 475 feet. The crude flowed out into a nearby river, where it ignited in a blaze that stretched for fifty miles downriver.

Drake's well was not the first well intentionally drilled for petroleum. A unsuccessful well had been deliberately bored for oil ten years earlier in France.

Why did Drake's well begin the oil industry (as it did)? Some of the causes might have been:

Drake happened to drill in one of the largest shallow fields yet found. Not only that, but the oil was "sweet," a type that could be easily converted to lamp oil by the primitive refining methods of the day.

By Drake's time, a demand for oil had been established through the work of the coal oil refiners. People had suitable lamps. Moreover, the spread of literacy in a TV-less age increased the demand for illumination strong enough for reading after sunset.

The site of Drake's well was relatively convenient to the transportation system and markets of the day.

The Internal Combustion Engine

Like other motor car manufacturers, Ford at first made expensive cars, and was urged by his board of directors to make even more costly ones. The Model B cost $2000 in 1904. Instead, in 1908 Ford brought out the Model T at a price of $850. By 1914 it was selling for $490. In its 18 years of manufacture, 15,000,000 cars were sold in a country poorly served by all-weather roads. Ford's car not only lead to the remaking of the road system; it remade American society.

New Molecules

The first success the chemists had was with "cracking," breaking down the large molecules of heavy oils to make lighter fractions like gasoline that were more in demand.

This experience lead on to synthesizing molecules never seen before, such as:

material	date of first commercial availability
polystyrene	1930s
Neoprene	1936
butyl rubber	1937
Nylon	1939
Mylar/Dacron	1950s

Gas Pipelines

The building of long-distance transmission pipelines did not begin until 1926, when a 170-mile, 22-inch line was built in Louisiana. In 1931, building of gas pipelines consumed 75 per cent of the total steel pipe tonnage produced, and 7000 miles were laid. By 1949 there were 346,000 miles of gas pipeline network.

Discovery Rate

Nineteen-eighty was a boom year for exploratory drilling, thanks to the increase in oil and natural gas prices. Note that the graph of discovery rate does not include the discovery of the giant field at Prudhoe Bay, Alaska, which would create a big bump in 1973.

Activities and Discussion Topics

1. Why do people need artificial light? What are some ways of getting it? What ways would Americans have had a hundred and fifty years ago?

2. Brine is salt water, which is found in the earth at some places. Why would people two hundred years ago have valued brine? What would they do with salt? What alternatives were there to salting down meat and fish?

3. What do we mostly use petroleum for today? When did people first begin using it for that purpose? List as many uses of petroleum as possible.

4. Examine the import-export graph. What has happened since the Second World War?

5. Consider using the lesson on depletion of finite resources on appendix p 3-37.

6. Consider using the lesson on coal vs gas as a domestic fuel on appendix p 3-15.

Mini-Quiz

1. When oil was first produced by drilling wells, what was its most important use? [as kerosene for lamps]

2. What historical development changed gasoline from a useless by-product to a highly sought after product? [the invention of the internal combus-tion engine, the spread of the automobile]

3. Why did it take so much longer for natural gas to become an important fuel than it took oil? [Gas had to wait for the development of a pipeline system that would reach major markets.]

4. What is the name of the factory that converts crude oil to gasoline and other petroleum products? [refinery]

5. In what decade did we begin to consume more oil than we produced ourselves? [the 1940s]

6. In what decade did domestic production of petroleum decline for a number of years? [the 1970s]

7. What country was the largest exporter of oil in the early years of petroleum production? [the United States]

8. Recently, the amount of oil we import each year began to decline. In what year did we import the most oil? [1977]

9. What do we call the special ways of getting more oil out of old wells that have stopped producing? [secondary recovery, give full credit for enhanced recovery or tertiary recovery]

10. Besides being burned as a fuel, petroleum is used to make lubricants. Petroleum is also made into a material from which things can be made. What are those materials called? [plastics]

True or False?

Most oil estimated to be still in the ground in the U.S. is off-shore. [F]

By 1900, long-distance natural gas transmission pipelines reached most parts of the United States. [F]

The more oil is worth, the more barrels of it we can get out of the ground. [T]

The oil industry began in Pennsylvania. [T]

There is no more oil to be discovered in the United States. [F]

There have been times in the past when Americans believed they were running out of an energy resource. [T]

Hardly anyone bothers to look for oil in the United States today. [F]

ENERGY FROM NUCLEAR FISSION (pages 16 & 17)

Reading Level (by Fry count): 12th grade (Because discussion of this topic requires the use of polysyllabic special vocabulary, this count does not accurately reflect the true reading level.)

Objectives

The student is aware that the radioactivity involves a change in the nucleus of atoms.

The student acquires a basic understanding of the workings of a fission reactor: a nucleus fissions, the motion of the resulting fission fragments produces heat, the heat can be used to run a steam turbine and generator.

The student recognizes that the nuclear fuel cycle produces wastes which require responsible long-term management.

Vocabulary

- nucleus
- electrons
- protons
- neutrons
- element
- isotopes
- radioactive decay
- chain reaction
- nuclear fission
- uranium
- breeder reactor

Background Information

Atomic Nature of Matter

Most students will have learned of atoms and particles in earlier years. The terms atomic number and mass number have deliberately not been introduced; but they might be appropriate in your classroom.

Isotopes

The two isotopes of hydrogen have their own names: deuterium (one neutron) and tritium (two neutrons). Tritium is the material used in the digital LCD watches that glow in the dark (the decay provides the energy for the glow).

The text states that most elements have isotopes because a few elements have only one isotope that is found in nature. However, if we include man-made isotopes, all chemical elements have more than one isotope.

Radioactive Decay

The radioactive decay of tritium, which is described in the text, produces a beta ray. There are other types of radioactive decay that produce other particles. The types of radiation produced are alpha particles (a helium nucleus thrown off at high velocity), beta particles, and gamma rays (which, unlike the other two, really are electromagnetic radiation.) Neutrons may also be emitted in some nuclear reactions.

When a nucleus decays, it turns into a nucleus of another chemical element, because there is a change in the number of protons. Every radioactive isotope has characteristic ways of decaying, each way producing some particular other element. The elements produced are called the daughters of the original element. The rate at which this change occurs is also characteristeric of each isotope.

The rate of decay is measured by half-life. A lesson plan on half-life will be found on page 4-3 of the appendix.

The measurement of the half-lives of naturally-occuring isotopes is the basis of the techniques used to date rocks and archeological remains. For example, when a rock is formed it probably contains a minute amount of some radioactive isotope. As time passes, the amount of this isotope decreases and the amounts of daughter isotopes increase. By comparing the two quantities, an estimate can be made of the time that has passed since the rock was formed.

Nuclear Fission

A lesson relating the energy from fission to Einstein's famous equation is provided on page 4-11 of the appendix.

While uranium nuclei can be fissioned by bombardment with neutrons, they will also fission spontaneously (a mode of radioactive decay). However, usually uranium decays in another way.

Isotopes that can be fissioned by a neutron are called fissionable; those that can be fissioned by a slow-moving neutron are called fissile. There are only three fissile isotopes and only one of these, U-235, occurs naturally.

...Some Definite Advantages

To compare the risks of various energy sources, it is necessary to compare the whole fuel cycle, not just individual parts of the system. Because nuclear power is only used to generate electricity, it seems sensible to compare it with the main presently available alternative, coal.

Radiation and Life

Very large doses of radiation kill outright, but this is not a cause for much concern (except in case of nuclear war or terrorism). Only 7 people have died of acute radiation poisoning in the entire course of U.S. nuclear energy, all of them workers.

Instead, the question is what the effect of low doses of radiation over long periods of time will be.

There are two effects:

One is somatic. For example, the survivors of Hiroshima had an increased incidence of leukemia, typically developing several years after the blast. The American women who painted luminous watch dials almost all developed bone cancer, due to the radium in the paint. (In Europe, workers doing the same job did not develop cancer, because they didn't lick the brushes to point them.) Sometimes the effects cannot be associated with a particular disease. Decades ago, radiologists had a shorter life span than other white male Americans. Gradually, standards on how much exposure was considered acceptable were made more stringent, and as this happened the lifespan of radiologists increased until it now exceeds the average of other white American males.

Another form of damage is genetic damage. In this case, the eggs or sperm of the person exposed are altered.

The faster cells are dividing, the more susceptible they are to radiation damage. That is why radiation can be used to treat fast-growing cancerous tumors. It is also why doctors are reluctant to x-ray unborn children.

In general, a given amount of radiation received in a single dose will be more harmful than if it were spread out over a period of time.

Background Radiation

Intensive efforts have been made to estimate the size of the various natural and man-made sources of radiation, mainly as a means of evaluating the effects of using nuclear power. One of the clearest ways of displaying a comparision between different sources was devised by the United Nations Scientific Committee on the Effects of Atomic Radiation, which every five years tries to summarize these effects. For each source, they estimate how many days exposure of the world population to the natural background radiation would be necessary to get the same exposure the world population gets from a particular source. So, for example, it takes 365 days of exposure to the natural background radiation to equal the exposure all humans get in one year from the natural background exposure.(1)

Source of Exposure	Days of exposure to natural background radiation needed to equal exposure to this source
One-year exposure to natural sources	365
One year of commercial air travel	0.4
Use of one year's production of phosphate fertilizers at the present production rate	0.04
One-year global production of electric energy by coal-fired power plants at the present global installed capacity (10,000,000 MW(e))	0.02
One-year exposure to radiation-emitting consumer products	3
One-year production of nuclear power at the present global installed capacity (80,000 MW(e))	0.6
One year of nuclear explosions averaged over the period 1951-1976	30
One year's use of radiation in medical diagnosis	70

This is the "dose commitment" for the population of the earth as a whole; figures would be higher for Americans because we have more consumer products, medical care, airplane flights, etc. than the average resident of Earth.

Some of the sources of radiation are:

Cosmic rays. As you go higher, this dosage increases, so that the cosmic ray dose in Denver would be twice what it would be at sea level. A cross-country round trip airplane ride adds an extra 10% from this source to the coast-dwelling traveller's annual dose.

Radiation from the radioactive elements in the ground. This varies with the geology of the place where you live. Texas is typically low and Wyoming high. Building materials also emit radiation. A person living in a stone house receives about 50% more radiation from the house than a resident of a wood house does.

Radiation from the air, which contains radioactive elements like radon.

Radiation from inside the body comes from naturally-occuring isotopes in food and water, principally potassium-40. The more you eat, the greater the dose. The lungs get by far the highest dose of any organ of the body.

The table above mentions radiation from coal plants--coal contains radioactive isotopes which are released when it is burned.

Consumer goods that produce radiation include products like watches (the largest single source), early color TV models, and smoke detectors. The latter is a good example of a trade-off in risk and benefit; the lives saved by early fire warnings greatly exceed any possible effect from the radiation emitted by these detectors.

Nuclear bombs continue to be tested in the atmosphere, contributing to the dose received from fallout. The twenty nuclear tests carried out between 1971 and 1976 increased the amount of radiation each person will receive in their lifetime (the so-called dose commitment) from fallout about 2% for people living in the Northern Hemisphere.

Medical x-rays, as can be seen, are a major source of exposure. Faster films, improved equipment, and more conservative practices are decreasing exposure from this source for most Americans.

Radioactive Wastes

The states have been very reluctant to allow a national nuclear waste depository to be established within their boundaries. One proposal has been to auction off this facility among states with suitable geology. The state that offered to store the waste for the lowest annual payment from the federal government would get the contract.

Because wastes have been created anyway by the nuclear weapons program, we will have to provide long-term storage even if we have no commercial nuclear power program.

What volume of wastes are we talking about? In a year's operation at 100% of capacity, a 1000 Mw(e) power plant will produce, after fuel reprocessing, 114 cubic feet of high-level wastes and an additional 72 cubic feet of "cladding," the metal tubes in which the fuel is packed to make fuel rods. After about a thousand years, the overall radioactivity of these high-level wastes will decay to the level of the original ore body. Of course, it is no longer safely underground, and a different set of isotopes has been created, which may be good or bad depending on how they are taken up by organisms. In addition, mining and processing the ore, operation of the reactor, and operation of the reprocessing plant result in other wastes or effluents which are less radioactive, such as 6900 gallons of intermediate-level wastes, 340,000 gallons of low-level liquid wastes, and 6900 cubic feet of buried solid wastes. The largest components of the released effluents are the noble gases xenon and krypton. In terms of volume, the reactor wastes are minuscule compared with the wastes produced by a coal-fired plant with equal capacity.

Accidents

Commercial power reactors cannot explode like a bomb. All American plants are fueled with a mixture of about 96½% uranium-238 and 3½% uranium-235. Bombs are made of 10% uranium-238 and 90% uranium-238, because to get the bomb to explode, one needs a chain reaction that proceeds very fast, before the material you want to fission is blown away. To do that as many as possible of the neutrons produced by fission must hit U-235 atoms. The uranium-238 atoms just get in the way by absorbing neutrons without fissioning. If the uranium used in a reactor were assembled into a regulation military A-bomb, the bomb would not go off. Within the reactor there is no way the two isotopes can be separated in order to concentrate the U-235. For this reason alone (there are others), light water reactors cannot explode like an A-bomb.

From the very beginning of commercial nuclear power, people have been much occupied with trying to predict the nature and frequency of occurrence of possible accidents involving nuclear power plants. The most recent effort is the government's Rasmussen report, and the critiques of it.

This is a complicated field of study but an important one, because there are risks to nuclear energy as there are with any energy source. One of the less publicized risks is financial: repairing Three Mile Island, for example, is now expected to cost a billion dollars.

Breeder

Interest in the breeder arises from the fact that over 99% of the uranium mined is U-238, which can't be used as fuel and is simply accumulating. The breeder converts this waste by-product to plutonium, which can be used as fuel. It is also much easier to make bombs of plutonium than of uranium-235, which has raised the spectre of nuclear proliferation if plutonium becomes common.

Some breeder cycles do not employ plutonium, but convert the element thorium to uranium.

Incidentally, a fast breeder produces less plutonium per year than today's light water reactors do, because the breeder is also burning up plutonium as it breeds it.

Pressurized Water Reactor

The reactor illustrated is one of the two types of Light Water Reactor (LWR) used in the United States. The other type is called the Boiling Water Reactor (often abbreviated BWR).

Activities and Discussion Topics

It does not seem possible to treat this field in a day or two. Beyond going over the contents of the reading with your class, you might wish to try some lessons. We have picked two that stand alone fairly well, if the class is motivated and has already learned about atoms and nuclei:

Half-Life of Isotopes, appendix p 4-3

Energy From Fission, appendix p 4-11

Mini-Quiz

1. What is the name of the type of reactor which uses extra neutrons to change an isotope that cannot be used as fuel into one that can be? [breeder]

2. What is the inner part of the atom called? [nucleus]

3. What is the correct term for "splitting the atom?" [nuclear fission]

4. When a reactor is operating, the rate at which it produces energy is controlled by controlling the number of what? [neutrons]

5. Energy produced in a nuclear reactor is extracted in what form? [heat]

6. What do we call it when the fissioning of one atom causes several other atoms to fission, and they cause still others to fission, and so on? [chain reaction]

7. Name the two main particles found in the nucleus. [neutron, proton]

8. Name one natural source of radiation. [Cosmic rays are mentioned in the text; there are other correct answers.]

9. A beta ray consists of what particle? [an electron]

10. Uranium 235 and plutonium 239 are both radioactive. What else do they have in common? [They can be split by slow-moving neutrons.]

True or False

The nucleus of one atom has three neutrons and two protons. The nucleus of another has two protons and two neutrons, so they are atoms of the same element. (T)

The number of protons in the nucleus is the only factor determining which chemical element it is. (T)

It is possible for some chemical elements to change into other elements. (T)

A commercial power reactor could explode like an atomic bomb. (F)

Some elements have some isotopes that are radioactive and some isotopes that are not. [T]

ENERGY FOR THE NEXT TEN THOUSAND YEARS (pages 18 & 19)

Reading Level (by Fry count): borderline between 7th and 8th grades.

Objectives

Students recognize the possibility that a transition to renewable energy resources will eventually be necessary.

Students recognize that appropriate use of renewable resources conserves other energy sources for other uses.

Students recognize that sunlight is converted to heat through absorption.

Students are aware of methods of using sunlight to meet the need for heat (for hot water and space heating) in a home.

Students are aware that heat can be transferred by circulating fluids.

Students are aware that heat can be stored through the thermal inertia of materials.

Vocabulary

solar collector
damper

Resources

Request a free set of the NSTA Fact Sheets from DOE/TIC, P.O. Box 62, Oak Ridge, TN. A Solar Energy Education Bibliography, (Expanded), which is annotated and very complete, is available for a $3.74 check made out to "Sundries" from the Center for Renewable Resources, 1001 Connecticut Ave. NW #510; Washington, D.C. 20036.

Modern Talking Picture Service (see your phone book for nearest regional office) offers a free-loan film (sponsored by Exxon) on solar architecture, Energy from the Day Star. Though the examples are upper-income homes, the possibilities are very well illustrated, and the film has no commercial message. We recommend it.

Background Information

The Need for Renewables

A point not mentioned in the text is that exploiting sunlight does not add to the earth's heat load, as do combustion, fission, and fusion. At the present time, this effect is noticeable only in the climates of cities, which are warmer than the surrounding countriside. However, if energy consumption were to continue to increase at the present rate, the heat added to the atmosphere could in time become a serious problem.

"Sunlight is the basic..." Economics and Efficiency

This section attempts to distinguish between capital costs and operating or maintenance costs.

Recent developments in plastic solar collectors for water heating provide a good example of trade-offs between cost and energy-efficiency, and illustrate the point that making improvements in efficiency regardless of the cost is not sensible. Ordinarily much more roof area is available for the collectors than is needed. On the other hand, the purchase price of the collectors is a serious obstacle. As a consequence collectors with plastic absorbers have been developed. They are easily fabricated and cheaper than collectors with metal plates, but they are also less efficient: they produce less heat per square foot. However, it can be cheaper to install a big, inefficient, plastic collector than a smaller, more efficient metal one that produces the same amount of hot water. Of course, if your demand for hot water outruns your roof area the situation is different.

Active Solar Water Heater

This is the kind of system that most people picture when they think of solar energy.

To keep things simple, the system chosen for illustration does not incorporate a heat-exchanger. It therefore would have to be made of approved sanitary materials throughout, because all parts of the system would come in contact with water people would drink. In freezing weather the system would have to drain itself automatically lest the water freeze and burst the collector.

To eliminate this risk, many systems use a heat exchanger. One loop of fluid circulates between the collector and storage tank, and anti-freeze can be added to this fluid. A heat exchanger in the storage tank keeps the antifreeze out of the drinking water while transferring the heat.

The functions of some of the labelled parts are:

Bleeder valve---used to purge air from the system.

Pressure relief valve---opens to prevent pressure increases from springing leaks in the collector plate or other parts of the system.

Check valve---allows the fluid to flow in only one direction. If fluid were allowed to flow in either direction, then at night when the collector was colder than the water in storage, convection would cause the warm water from the tank to flow up to the collector and cool.

This phenomenon, called thermosiphoning, is exploited in passive solar water heating systems. These need no pump, but the storage tank must be higher than the collector, so that heated water can rise to it. These are the most cost-effective of heaters, but they are seldom installed because of the awkward location of the storage tank.

Active Solar Space Heating

Note that the system has basically the same components as the water heater: a collector, a fluid which is used as a means of transferring heat (air), and a thermal mass (the bed of rocks).

Passive Solar Space Heating

This is an extremely important topic, which can probably have a greater impact on the nation's energy use than any of the active solar systems.

Passive solar has the same three elements as active, but the house itself is the collector and the thermal storage mass. Those three elements are:

some way of collecting sunlight as heat
some way of storing heat
some way of transferring the heat to where we want it.

The house pictured uses what is called a Trombe Wall. Sunlight entering a glass window-wall strikes a massive wall and is converted to heat. The heat is stored by virtue of the heat-retaining properties of the masonry of which the wall is made. The heat is transferred to living quarters inside by radiation from the inside surface of the wall, which is not controlled but will be fairly even throughout the day because of the wall's thermal inertia. It is also transferred by convection currents through openings at the top and bottom of the wall, and this circulation can be controlled.

The solar greenhouse is similiar to the Trombe Wall. It differs from from an ordinary greenhouse in incorporating large thermal mass.

Passive design can also provide ventilation by arranging openings in the house walls to take advantage of prevailing winds. Even where there is little window, architects can take advantage of convection currents within a house to exhaust the hotter air.

An essential part of any passive solar design is thorough insulation.

We think the best book so far for teachers who want to learn more about passive solar is The Passive Solar Energy Book, by Edward Mazria. (softbound edition, $10.95 from Rodale Press, Emmaus, PA.) Highly recommended.

Plants

In many parts of the world, plants are currently the main source of fuel. In fact, for much of the earth's population, the present energy crisis is the firewood crisis, caused by deforestation; and not our petroleum crisis.

Several United States cities are currently using plants as fuel, but the fuel mainly comes from wastes and thus is subsidized by previous uses. Several cities recover methane from fermentation of sewage or of materials in landfills.

Photovoltaic Cells

They last for decades and are maintenance-free. Most of those in current use are made of thin slices of huge crystals of silicon. Costs have fallen dramatically since they were first produced for the space program. If the cost of the crystal can be lowered through some mass-production technique, such cells will become cheaper. Meanwhile, other workers are searching for alternative ways of directly converting sunlight to electricity or fuel. Some devices use semiconductor substances other than silicon. Some use many tiny silicon crystals on a panel submerged in a solution to produce hydrogen by a process like electrolysis. Still other researchers are trying to duplicate photosynthetic-like processes in a test tube. Any or all of these approaches may lead to a breakthrough.

Windmills

Most students think of Holland when they think of windmills, but as a matter of fact our plains might never have been settled without the windmills which provided water for irrigation and livestock before rural electrification.

A fine free-loan film on wind, Gusts of Power, (14 min) is available from the DOE/TIC, P.O. Box 62; Oak Ridge, TN.

Geothermal

Hot steam like that found in the Geysers field near San Francisco is rare. Warm water, while it not suitable for the production of electricity, is being used to warm schools, houses, and commercial greenhouses in various parts of the country. Experiments are going on to find ways of using hot dry rock.

Geothermal power is often polluting (hydrogen sulfide, radon) if air pollution abatement equipment is not used.

Fusion

Contrary to a common misconception, fusion energy using the reactions presently contemplated does produce radioactive wastes, because the escaping neutrons irradiate the reactor materials and create radioactive isotopes. It also appears that fusion reactors, if they can be built, will be much larger and more expensive than fission reactors.

Activities and Discussion Topics

If you have not already used the bead fling lesson on depletion of fossil fuels (appendix p 3-37), you may wish to consider using it before beginning the discussion of renewables.

I. What are renewables?

II. Discuss role of renewables. Why might people be interested in their development?

Possible responses:
increase self-reliance, personal or national security
save money
get ready for anticipated future

III. Study the diagram of the active solar water heater.
1. Where is the sunlight converted to heat?
2. How is the heat circulated?
3. Where is the heat stored?
4. What does the control box do?

IV. Study the diagram of the active solar space heater.
1. Where is the sunlight converted to heat?
2. How is the heat moved from place to place?
3. Where is the heat stored?
4. What are the dampers used for? How would they be set in each of the following situations (to facilitate reference to them, ask students to number the dampers in their booklets):
   a. The sun is shining brightly but the house is warm enough.
   b. It is night. The house needs heat.
   c. The sun is shining and the house needs heat.

We have chosen to include in the appendix the sequence of activities on the movement of the sun. Understanding the sun's movement is fundamental to passive solar design, and less importantly, to the use of concentrating collectors. The sequence begins by establishing the concepts of bearing (app p 5-3) and altitude (p 5-5). Making a record of the sun's movement for a day (app p 5-7) and then transferring it to Cartesian coordinates is a hands-on way of explaining the meaning of a sun angle chart. After students see how they could do it for themselves if they had a year to make observations, they are given a sun angle chart for their latitude. These lessons lead to passive solar design. Here, one example of

the transition to passive solar will have to suffice.

Take the sun angle chart for the even latitude nearest to your own latitude (please have it in hand as you read this explanation). Suppose you have a room with south-facing windows. It is too warm in the summer, too cold in the winter. What can we do?

If we look at the chart, we see that the winter sun is much lower in the sky than the summer sun. Draw a line through the chart so that it is just above the sun at noon on March 21. Suppose we make an awning that hangs down just this far. On March 21, the sun will shine into our room all day long. That's good, because we're too cold. But on June 21, the sun will disappear behind the awning early in the morning and stay there until late afternoon. That's good, because in June we're too hot. From the sun angle chart, we can tell exactly where to put our overhangs.

Mini-Quiz

1. How is heat transferred from a solar collector into a house? [by a circulating fluid like water or air]

2. What keeps a solar-heated home warm when the sun isn't shining? [heat is taken from storage]

3. Name a device that converts sunlight directly to electricity. [photovoltaic cell]

4. Name a material that would be good for storing heat in a solar house heating system. [water, rock, masonry]

5. What is the name of the type of solar heating that does not use any pumps, and uses the house itself as the collector? [passive solar heating]

6. Around 1900, solar collectors were popular in some parts of the country. Why was their use largely discontinued? [Petroleum and gas were cheap.]

7. It is easiest to turn sunlight into what other kind of energy? [heat]

8. What is the name of the kind of reaction from which the sun gets its energy? [fusion]

9. What is the name of the kind of energy we get from hot rocks in the earth? [geothermal energy]

10. What is the name of a valve in a chimney or air duct that can stop the flow of air? [a damper]

True or False?

North-facing windows help to warm a house. (F)

More than half of the nergy used in homes is used to heat air or water. [T]

An active solar water heating system needs electricity to operate. [T]

ENERGY...THE MORE WE HAVE...THE MORE WE USE... THE MORE WE WANT (pages 20 & 21)

Reading Level (by Fry count): 8th grade

Objectives

Students are aware of the large per capita increase in energy consumption by Americans since 1900.

Students are aware that there has been a shift in energy sources.

Background Information

1700

The Iroquois were chosen rather than the colonists in the year 1700 because they represent a pre-machine, pre-fossil fuel society. Such societies still exist; in fact, people like the Tasaday of the Philippines are today less advanced technologically than the Iroquois were in 1700.

1800

By 1800 Americans in the large Atlantic coast cities like Philadelphia and New York had begun to use coal, but the amount was too small to show up on a graph at this scale. Water power was also in use, especially in New England, and New York had some windmills. None of these provided enough energy to be visible on a graph at this scale. Wood was far and away the primary energy source.

Contrary to a popular impression, Americans of the late colonial period were not frugal in their use of energy, if we compare them to Europeans of the same period. The chief reason for this high level of consumption was the national project: making farms out of a virgin wilderness. To do this, trees had to be cut down and disposed of. On the frontier, all the firewood one wanted could be had for the labor of cutting it, with the grateful thanks of the landowner. Another reason energy consumption was so high was that pioneers lacked capital. They did not have money to buy iron stoves, glass for windows, oil and lamps, or other goods that would have made possible less energy-intensive ways of doing things. An enormous fire in an inefficient open fireplace was lamp, heater, and stove to most colonials.

By 1800, this was changing, and the change was first felt in cities. Wood was getting dearer; housing better; stoves more common. The nation was poised for industrial expansion.

1900

By 1900 America was essentially an industrial nation. Coal was the primary energy source. Petroleum was primarily a fuel for lighting; automobiles were curiosities.

1979

Notice that for 1979, the Homes, Stores, Offices category is subdivided into Space Heating, Cooking, Water Heating, Refrigeration.

Exponential Growth

Turn the student booklet sideways, so that the years are on the bottom. Now the end of each line represents per capita energy consumption in some particular year. If we imagine a line drawn through the ends of the lines, its general shape is that of an upward sloping curve. (If we had figures for more years, we would have the same general shape plus a lot of squiggles for events like the Great Depression.) If each year, each person had increased their energy consumption by a fixed amount, say an additional 100 gallons of gasoline, this curve would be a straight line. It is not a straight line. This shows that each year's sonsupmtion is some multiple of past consumption. For example, for many years, consumption of electricity increased around 7% a year. (That steady growth made planning pretty easy for utilities. Now the growth rate is down, and what is worse for the planners, it has become very hard to predict what it will be a decade ahead.)

The difficulty with growth rates like this is that the more time passes, the faster things happen. It is like the adviser who got the king to pay him one grain of wheat on the first square of the chessboard, two on the second, four on the third, and so on. There was not enough wheat in the world to pay such a debt. If you stop and think about it, you will see that such growth cannot go on forever; the only question is how long before we run out of whatever necessity is in shortest supply, and what we can find to substitute for it.

Activities and Discussion Topics

Reading a Bar Chart

1. First confirm that the students understand how to read bar charts in which there are bars within bars.

Tell the class pages 20 & 21 are a kind of bar graph, laid on its side. Have students identify the key or legend. Ask them to write on the bars the names of the energy sources in 1800. Now write the names of the uses in 1979. If there isn't room to write out the word on the bar, write it in the surrounding white space and connect the word to the bar with a line. Use this deskwork to confirm that students understand how to use the key.

2. Now confirm that students are able to use a scale.

Ask them to find the scale at the top of the graph. The vertical lines are one centimeter apart.

How many Btu's did an average Iroquois use in 1700? [10 million]

How many Btu were used for transportation in 1900? [30 million Btu per person]

3. Ask students to use a metric ruler to measure the length of the bar for transportation in 1979. How many Btu does it represent? [about 8,900,000 Btu]

4. A worksheet is provided on page 49 which students may be asked to complete in class or as homework.

Discussing Our Energy History

In the appendix of this book is a selection of readings on America's Wood Age which may be helpful in bringing America's energy history to life for your students. Each is accompanied by study questions for students. Here are some points for class discussion:

Captain John Smith: Off to the Wilderness (app p 6-3)
- What were the available energy sources?

Benjamin Franklin: The Newly Invented Fireplace (app p 6-7)
- What was the fuel situation?
- What was Franklin's response?

Captain Edward Marryat: Transportation in America, 1830

Marryat: Salt
- Can wood be a fuel for industry?

Marryat: No Midwestern Industry (app p 6-22)
- What energy sources were used for manufacturing in the 1830s?
- How do people make mistakes in foretelling the future?

Mark Twain: The End of Steamboating Days (app p 6-23)
- Why did the steamboat decline?
- Why did the woodyard man vanish?

Laura Ingalls Wilder: Sudden Storm (6-29, Candlemaking (6-32), Icecutting (6-35).
- Compare how the rural Americans got heat, light and cold in the late 1800s and how we do it today.

Talking about Horses (6-38), A New Plow (6-39), A Sewing Machine (6-41)
- How did machines enable people to make better use of the muscle power available to them?

Mr. Ingalls Threshes (6-43), Mr. Wilder Threshes (6-46)
- How do people's attitudes to labor-saving machines differ?
- Do people have different attitudes today?

Critical Thinking

What might be some of difficulties of gathering statistics like these?

Did the Iroquois keep energy consumption statistics? How could an anthropologist go about estimating the energy consumption of a vanished society? What kinds of records might the Americans have kept in 1800? How would an historian go about estimating energy consumption in earlier periods?

Which energy sources might be hardest to keep track of today? Does that mean they are undercounted?

Mini-Quiz

1. What was the chief fuel in 1800? [wood]

2. What was the chief fuel in 1900? [coal]

3. What was the chief fuel in 1979? [petroleum]

4. In 1800, which used more energy, homes and stores, or industry? [homes and stores]

5. In 1979, which used more energy in homes, stores, and offices: space heating or water heating? [space heating]

True or False

Between 1900 and 1979, there was a great increase in the proportion of the percentage of total national energy consumption used by industry. [False]

Worksheet

Turn to page 20 of your booklet. Circle the right answers or fill in the blank.

1. In 1900, which used more energy per person, transportation or industry?
2. In 1979, which used more energy per person, transportation or industry?
3. Which produced more energy per person in 1900, hydropower or wood?
4. In 1979, which used more energy in homes, cooking or water heating?
5. Which energy sources were important enough to show up in 1900 but were not in 1800? _____
6. Which energy sources were important enough to show up in 1979 but did not show up in 1900? _____

****

Using a Scale
To answer these questions, you will need a ruler marked in millimeters. Write the answers in the space provided.

1. Find the scale. It says that 1 centimeter = _____ Btu.
2. Then 1 millimeter will equal _____ Btu.
3. A bar 3 centimeters long represent would represent _____ Btu.
4. In 1800, coal supplied _____ Btu.
5. In 1900, industry used _____ Btu.
6. In 1979, industry used _____ Btu.

****

Comparing Numbers

1. The people in 1800 used _____ times more energy per person than the Iroquois did.
2. About _____ per cent of the energy used in 1979 was used for cooking.

ENERGY PRODUCTION & CONSUMPTION... HERE IT COMES, THERE IT GOES (pages 22 & 23)

Reading Level (by Fry count): 8th grade

Objectives

The student is aware of the relative magnitude of present-day energy sources and uses.

The student is aware of which energy sources presently support particular uses, such as dependence of transportation on petroleum and extensive use of coal for electrical generation.

Background Information

This chart is based on the most recent data available at the time of publication. You may wish to discuss with students why the most recent data would be for 1979, i.e., it takes time to collect and compile statistics. In the same vein, you might wish to discuss differences in the difficulty of monitoring different kinds of energy sources and uses: e.g., it is relatively easy to find out how much electricity households use, but very difficult to find out how much firewood.

The statistics on which this chart is based lump agricultural activities with other industrial and commerical energy use. Agriculture is estimated to use about 17% of total U.S. energy consumption (earlier estimates were around 12%, including about 22% of all electricity consumed). A 1974 study divided estimated annual per capita energy use for agriculture as follows:

agriculture (farm, fertilizer, etc)	5.8 million Btu
food processing	10.6
transportation	0.9
wholesale and retail trade	5.2
home	9.9
total	32.4

Some students make the mistake of thinking that the top band flowing into a block must power the top line out. For example, referring to the "Transportation" block, powering pipelines is NOT exclusively the job of natural gas; and similiarly in "Residential," electricity is obviously not just used for space heating.

Some of the phrases on the chart may need interpretation:

"Extraction loss and reservoir reprocessing" includes such things as oil spills and the use of petroleum or its products to maintain production in a field.

"NGPL" is natural gas plant liquids, liquids which condense out of natural gas during its processing.

"Space heating" means, for example, heating homes or offices for purposes of comfort.

In the industrial blocks:

"Primary metals" are industries that convert metal from ore to the form in which they go to fabricators.

"Process steam" is steam which provides heat and sometimes water itself for a process. This does not include, for example, the steam produced in an electric power plant.

"Electric drive" is electric motors.

"Electrolytic process" are, for example, the electrolytic refining of aluminum and copper.

"Feed stock" is coal, oil, and gas used to make substances like plastic or lubricating oil.

Activities and Discussion Topics

If your class is quite familiar with graphing, you may want to move immediately to examining the diagram. Other classes may benefit from approaching the flow diagram through some simpler diagrams of the same type. A worksheet for doing this begins on page 54.

Worksheets for examining the flow diagram itself are provided on pages 56, 57, and 58. Before assigning the sheets, be sure students understand that in the graph all energy is measured in Btu's, a unit of heat. The sources are not measured in physical units like gallons of gasoline or tons of coal. This way, we can compare different sources. (On the other hand, 100 Btu's of one source may be inherently more useful than 100 Btu's of another.)

The names of the sheets and the topics they treat are:

Energy Sources in the United States

The exercise asks students to compare the contribution of various energy sources, and the relative sizes of the different uses made of a source.

Energy Uses in the United States

This exercise asks students to compares the amounts of energy needed for various purposes.

Getting the Numbers Right

The exercise provides practice in the use of a scale and in computing percentages. It reinforces points made in the previous sheets but adds nothing new.

Efficiency of Energy Use in the United States

The purpose of this sheet is to bring out the large potential for conservation available through increased efficiency. For example, the waste heat consequent to the generation of electricity might be put to some use, perhaps through cogeneration.

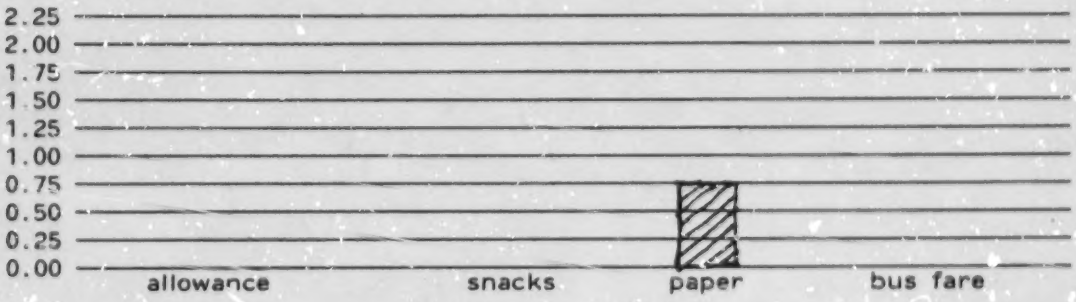
Study of this flow chart can lead into having the students contruct a similiar flow chart for their own household. Forms for this purpose are on appendix page 6-69 and 6-70.

Worksheet

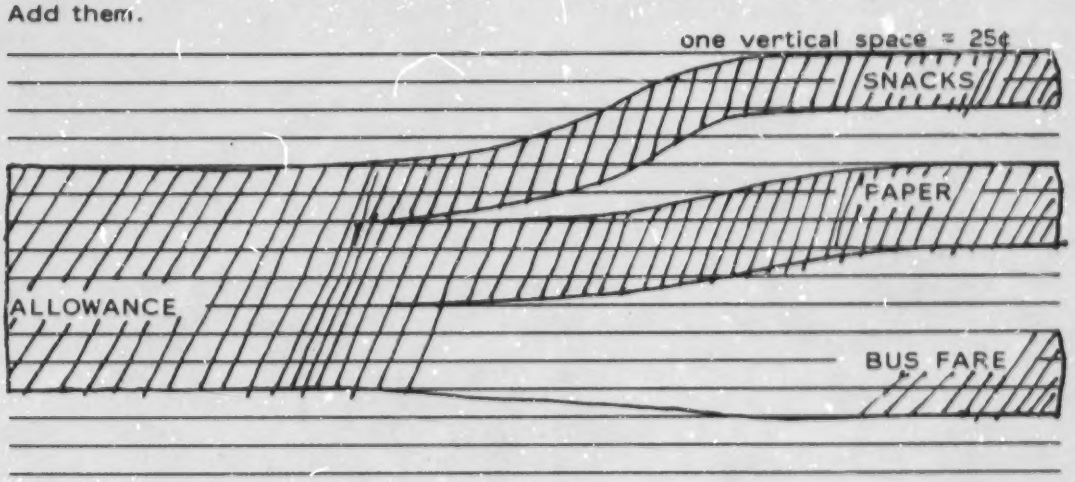
A Kind of Graphing

In this activity you will learn about a new kind of graph, which is related to a bar graph.

Part One: A junior high student got a $2 a week allowance. He spent it on snacks (50¢), notepaper for school (75¢) and bus fare (75¢). Using the form below, make a bar chart of Bill's income and expenses. One of the bars is done for you.

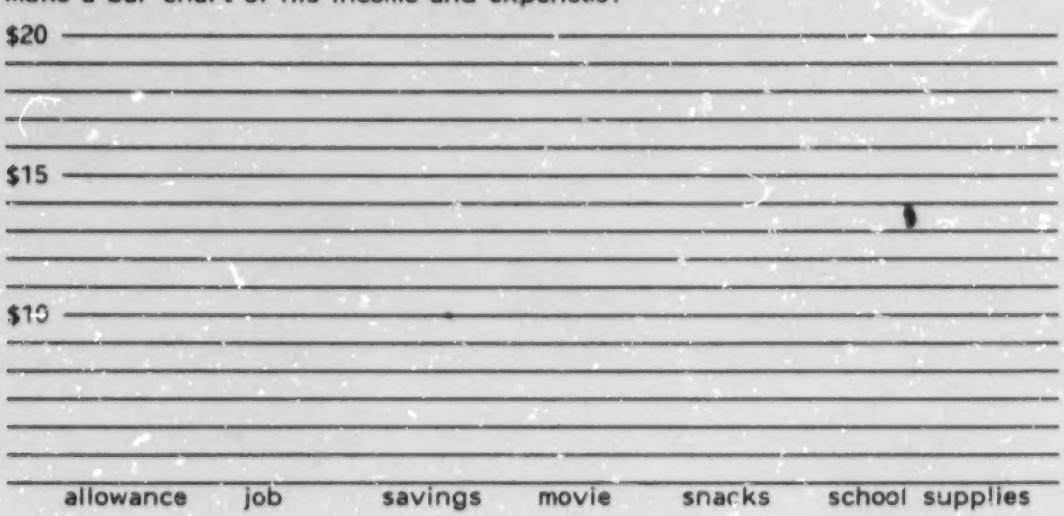


The amount Bill gets as allowance is exactly as large as his total expenses. After all, the money goes in and out of the same pocket. We can make a new chart that shows this. Some of the lines and shading are missing. Add them.

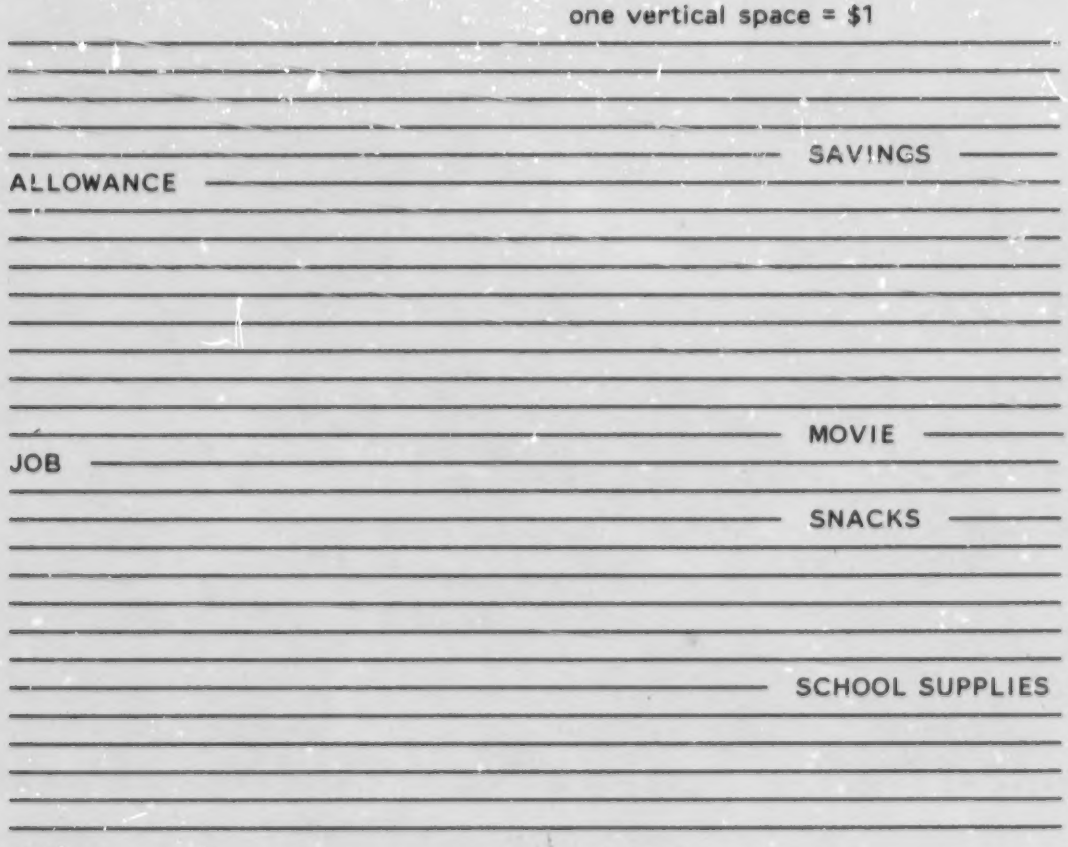


Part Two:

Moving up in the world, Bill gets a job and earns $15 a week in addition to the $2 allowance. Now he spends it on a movie ($2), snacks ($1), bus fare ($1), school supplies ($2) and he saves $11 for a motorcycle. Make a bar chart of his income and expenses.



Now make a diagram of his new situation by adding the missing lines and shading with your pencil.



Activity Sheet

Energy Sources in the United States

Answer these questions by studying the energy flow diagram on pages twenty-two and twenty-three of your Energy 80 booklet. You may need to use a ruler, preferably one marked in millimeters. Write the answers to the questions on a separate sheet of paper, numbering your answers.

1. This diagram provides a picture of United States energy use in what year?

2. What is the largest single source of energy used in the United States?

3. What was the largest single source of domestically-produced energy (not counting the imported energy)?

4. What were the three largest sources of the energy used to generate electricity?

5. What energy source provided most of the energy used in transportation?

6. What energy source provided most of the energy used in the home?

7. What form of energy did we export the most of?

8. What form of energy did we import the most of?

9. What was the largest single use for coal?

10. What was the largest single use for petroleum?

11. What was the largest single use for natural gas?

12. Which provided the greater amount of energy, coal mined underground or surface-mined coal?

13. Was more natural gas obtained from oil wells or from wells drilled specifically for gas?

14. Which used more natural gas, homes or industry?

15. Aside from its use for generating electricity, only one sector consumed significant amounts of coal. Which one?

16. Which of the three energy-using sectors used too little electricity for it to be visible on the diagram?

Activity Sheet

Energy Uses in the United States

Answer these questions by studying the energy flow diagram on pages twenty-two and twenty-three of your Energy 80 booklet. You may need a ruler, preferably one marked in millimeters. Write the answers to the the questions on a separate sheet of paper, numbering your answers.

1. Of all industrial uses of energy (except "other"), which two used the most energy?

2. Which used more energy, homes (residential) or transportation?

3. What mode of transport used the most energy?

4. Which used more energy, railroads or airplanes?

5. Which used more energy, trucks or railroads?

6. Is it possible to tell from this diagram which used less energy to move one ton of freight one mile, an airplane, a truck, or a railroad? Explain your answer.

7. List in order the two largest uses of energy in residences, not including "other".

8. What was the largest single use of energy in the commercial sector?

9. Two other industries used about the same amount of energy as the concrete, stone, clay and glass industry did. What are the other two?

10. Which used more energy, running automobiles or heating homes?

Activity Sheet

Getting the Numbers Right

Answer these questions by measuring the energy flow diagram on pages twenty-two and twenty-three of your Energy 80 booklet. You will need a ruler marked in millimeters. Write the answers to the questions on a separate sheet of paper. Show your calculations, if any.

Using a Scale Factor

1. How many quadrillion BTU did petroleum provide?

2. How many quadrillion Btu did natural gas provide?

3. How many quadrillion Btu did the United States use in all in 1979?

Calculating Percentages

Carry your answers out to the nearest whole percent.

1. What percentage of the energy used in homes was used for space heating and water heating together?

2. What percentage of the energy used in transportation was used by automobiles?

3. What percentage of the energy provided by natural gas was used to generate electricity?

4. Of the total electricity generated, what part of it came from natural gas?

5. What percentage of the energy used in industry was used to run electric motors ("electric drive") and for chemical processes using electricity (like the "electrolytic process" for producing aluminum)?

6. What percentage of the energy used in industry was used in petroleum refining?

Activity Sheet

Efficiency of Energy Use in the United States

Answer these questions by studying the energy flow diagram on pages twenty-two and twenty-three of your Energy 80 booklet. You may need to use a ruler, preferably one marked in millimeters. Answer the questions on a separate sheet of paper, numbering the answers.

The Red Arrows

In the diagram, waste heat is colored red for emphasis. All energy eventually turns to heat. Every time we use energy we convert it from one form to another, and part of it changes to heat whether we want heat or not. The energy used at home, in stores and industry, eventually becomes heat. Even the energy of a moving automobile is changed to heat when we put on the brakes. Finding uses for this "waste" heat is one of the most promising ways of getting more use out of the energy we use.

1. Is energy used more efficiently in transportation or in homes? Why do you think this is so?.

2. Compare the efficiency of nuclear power and hydropower in generating electricity. What accounts for the difference?

3. What is the overall efficiency, for the 1979 mix of sources, of the electrical generation process?

4. What are some uses that could be made of this waste heat?

Answers to Activity Sheet Questions

Energy Sources in the United States

1. 1979
2. petroleum
3. natural gas
4. coal, petroleum, natural gas
5. petroleum
6. natural gas
7. coal
8. petroleum
9. generating electricity
10. transportation
11. industrial
12. surface-mined coal
13. wells drilled for gas
14. industry
15. industry, industrial
16. transportation

Energy Uses in the United States

1. chemical industry, primary metals
2. transportation
3. automobile
4. airplanes
5. trucks
6. No, it is not possible. The chart tells us only the total amount of energy used in particular ways, not how much was accomplished by using that energy.
7. space heating, water heating
8. space heating
9. food (processing), paper industry
10. automobiles

Getting the Numbers Right

Using a Scale Factor

A range is suggested for the right answer because students can only be expected to measure with a certain precision.

1. 67 or 68 quadrillion Btu.
2. 33 or 34 quadrillion Btu.
3. 120 or 121 quadrillion Btu.

Calculating Percentages

1. 69%
2. 52%
3. 19%
4. 20%
5. 39%
6. 13%

Efficiency of Energy Use in the United States

1. Homes. Much of the energy use in homes is converting other forms of energy to heat, which can be done at very high efficiencies. In transportation, other forms of energy are converted to work in lightweight machines, and the efficiency cannot be as good.

2. The hydropower is shown being converted to electricity at an efficiency of almost 100%. This is really only the efficiency of the generator; we don't take into account the energy lost in the weather, the eroding of stream beds, and other places in the water cycle. Nuclear power, like the other major sources of electricity, depends on a heat engine, the turbine. Heat engines cannot change 100% of the heat to motion. (Actually, nuclear reactors are a little less efficient than fossil-fuel fired power plants, because the reactor doesn't reach as high a temperature as a boiler does.)

3. 32%. (10 divided by 10+21)

4. It could be used to heat nearby homes, businesses, or stores, to raise warm-water fish, to heat heavy oil underground, and so forth.

INVESTING IN ENERGY: MONEY OUT, MONEY IN (pages 24 & 25)

Reading Level (by Fry count): 8th grade (excluding tables)

Objectives

The student realizes that economic analysis may be used to prioritize investments in energy conservation and production.

Resources

A good low-cost three-week unit on energy and economics is Energy Tradeoffs in the Marketplace, prepared by the Washington State Council of Economic Education. Contact Donald Wentworth, Center for Economic Education; Pacific Lutheran University; Tacoma, Washington 98447 for up-to-date information on its availability. A PEEC module, Energy as an Investment Choice, (grades 9-12) is available free from DOE/TIC, P.O. Box 62; Oak Ridge, TN.

Background Information

Why a 9% Interest Rate?

In the examples, a 9% interest paid by the bank is assumed in order to use a market rate of interest, not a rate set by law, as most rates offered by banks and savings institutions are.

When there is no inflation, the market interest rate has usually been observed to be about 3%. If the rate of inflation is 7% (as the examples explicitly assume), one would expect to be able to loan funds and receive a 10% rate of return. In fact, at the time of writing the prime rate was at 20% and money market accounts paid 16% interest.

The table on the nest page may be made into an overhead transparency to show year by year what happen to the money.

In unit 7 of the appendix will be found a few consumer education lessons, one on appliance labelling and one on incentives to conserve. As a sample of next year's lessons, we have also included masters for our own play money, in hopes it might be useful to you for your own simulations in economics.

Activities and Discussion Topics

If students take away only one idea from this page, it should be that there are rational ways of choosing what the best investment is. A corollary is that once you have figured out what is most likely to bring the greatest return, taking that action is what is likliest to make it possible for you to do the alternatives as well.

Perhaps the best way of reviewing this spread is to work out the two cases on the chalkboard with the students' help. You can follow this by trying some real-life local examples. Utilities and building supply yards often have literature with estaimates of local costs and savings for various steps. Choose projects appropriate to the homes of the students.

SAVINGS

Year	$ at Beginning	Interest	Money at End
1	50,000		
2		4,905	59,405
3		5,346.45	64,751.45
4		5,827.63	70,579.08
5		6,352.12	76,931.20
6		6,923.81	83,855.01
7		7,546.95	91,401.96
8		8,226.18	99,628.13
9		8,966.53	100,594.66
10		9,773.52	118,368.18
11		10,653.14	129,021.32
12		11,611.92	140,633.24
13		12,656.99	153,290.23
14		13,796.12	167,290.35
15		15,037.77	197,161.89
16		17,744.57	214,906.47
17		19,341.58	234,248.05
18		21,082.32	255,330.37
19		22,979.73	278,310.10
20		25,047.91	303,358.10
21		27,302.22	330,660.24
22		29,759.42	360,419.66
23		32,437.77	392,857.43
24		35,357.17	428,214.60
25		38,539.14	466,753.91

BUYING ENERGY ABROAD (pages 26 & 27)

Reading Level (by Fry count): 9th grade

Objectives

Students identify petroleum as the leading commodity in international trade.

Students recognize that we are buying about half of our petroleum abroad.

Students recognize that one cannot buy more than one sells indefinitely.

Students suggest some difficulties our large dependence on foreign supplies might create.

Vocabulary

exports	Middle East
imports	[Arab Oil Embargo of 1973*]
[balance of trade*]	

*Words or phrases not occurring in reading but useful in discussion.

Background Information

14.7% of 1978 world trade, by value, was petroleum. For comparision's sake, according to United Nations' statistics the next nine most valuable categories of goods traded were:

motor vehicles	6.8%	electrical machinery	1.9%
non-electric machines	3.6%	telecommunications equip	1.5%
iron and steel	3.1%	organic chemicals	1.5%
clothing	2.0%	non-electric power machinery	1.4%

So petroleum trade is more than twice as valuable as the next most valuable item, motor vehicles.

In general, trade between nations enables goods to be supplied at the lowest possible cost, by the most efficient producer. If the Middle East will provide oil at a lower price than domestic production can, it benefits our economy to have access to the least costly source of energy. But, because the good being supplied is energy, on which most aspects of the economy hinge, other considerations also become important.

1) National security. Petroleum is the lifeblood of our economy as presently constituted, especially the transportation sector, and an interruption of supply could be catastrophic.

2) A severe balance of trade deficit.

Is OPEC Doing Us a Favor or Robbing Us?

As the oil-producing nations have often pointed out, it is not necessarily in their interest to sell us oil now. Many of the oil-exporting nations are currently receiving much more income from oil than they can spend in developing their countries. The left-over money must be invested. On the other hand, maybe they could make more money by cutting back petroleum production, leaving the oil in the ground. Since less oil would be available, that would raise oil prices, which are rising anyway. The value of the oil ten years from now (it would certainly still be there) might be greater than the value of the oil now plus the money they could make in ten years from investing them money from a sale now.

The Oil Embargo of 1973

A common misstatement is that OPEC created the oil embargo of 1973 during the Arab-Israeli War. Actually, the embargo was only by the Arab members of the organization. The non-Arab states continued to supply oil. In addition, at the beginning only the United States and the Netherlands were embargoed. Later Rhodesia, Portugal, and South Africa were added.

Activities and Discussion Topics

1. How many different colors of arrows are there? Find the legend that explains the meaning of the colors.

What does the width of the arrows indicate?

Which arrows are wider, the red petroleum arrows or the black gas arrows? Why?

2. Identify the countries or regions from which the larger red arrows are coming. Write their names on the map.

3. Identify the countries or regions to which the oil is going. Write their names on the map.

4. The oil arrows reaching Japan and the U.S. are about the same size. Does this mean they consume the same amount of oil? Why not?

> Be sure the class understands that the map does not show oil or gas that a country produced and used itself, only flows between countries.

5. The chart on pages 22 & 23 shows that in our country gas provides about half the energy oil does. Can you think of any reasons why the trade in natural gas is so much smaller than the trade in oil?

> Note the black arrows going from Alaska and Indonesia to Japan, and from Algeria to Europe and the eastern U.S.. This is Liquified Natural Gas (LNG), carried in tankers at temperatures below minus 260° F. (Some of the Algeria--U.S. shipments have been cut off because of a price dispute.)

6. Where do you think the arrows would go for these commodities:

motor vehicles	wood
wheat	iron and steel

7. Could the amount of oil we import each year decrease at the same time as the amount of money spent on foreign oil increases? How?

Compare this situation with the situation of a family that practices conservation but sees their utility bill rise. What would happen if they didn't practise conservation?

8. The drawing shows the oil exporters with dollars. Why would they be willing to take dollars for their oil? What are the dollars good for?

You can make discussion of this topic more concrete by having some foreign currency. Show the students the money and ask if the local hamburger stand would accept it. Who might? Why?

10. What does our community produce to trade with people overseas for the petroleum we are using?

Make a rough estimate of the value of the imported oil used by your community by multiplying the number of people times 12 barrels (a national average per capita consumption of imported oil) times $38, the marginal price per barrel in January, 1981. Your community would have to export goods or services, or obtain foreign investment of this amount to balance oil imports (and don't forget cars, clothing, and everything else we import).

11. Suppose <u>all</u> the candy bar makers got together and agreed to raise the price of candy bars to $20. What would happen to sales of candy bars?

There are limits to what a cartel or monopoly can do. These limits are set by the demand curve: how much buyers are willing to buy at different prices. OPEC would not be able to raise the price of oil if demand were not so great. Even if there were no OPEC, oil prices would rise because world demand has been rising. Can you think of any reasons why world demand for oil might have risen in the last twenty years?

<u>Mini-Quiz</u>

1. What is the biggest item in international trade? [oil]

2. What country buys the most oil? [the United States]

3. From what country do we import the most oil? [Saudi Arabia]

4. Name an African nation from which we import oil. [Nigeria]

5. About how much of the oil we consume is imported? [about half]*

6. About how much did we spend on imported oil in 1980? [80 billion dollars]

* Review question on related topic introduced in an earlier lesson and reviewed in class discussion during this lesson.

SAVING ENERGY DOLLARS AT HOME (pages 28 & 29)

Reading Level (by Fry count): 6th grade

Objectives

The student recognizes that the control of heat is the single most important means of home energy saving.

The student learns a number of techniques for controlling heat.

The student becomes aware of some unnecessary uses of energy in the household, such as forcing air through dirty filters, lighting and heating unused areas, and using hot water for all laundry.

Vocabulary

space heating
weatherstripping
caulking
insulation

Useful Demonstration Materials

insulation samples
caulking gun
piece of weatherstripping
furnace filter

Resources

Request free copies of the pamphlets Tips for Energy-Savers (EDM-064, also available in Spanish as EDM-065) and Low-Cost, No-Cost Energy Savers (CS-330) from DOE/TIC, P.O. Box 62, Oak Ridge,TN. The most practical booklet of ideas for low-income families is Save Energy: Save Money, distributed by the Office of Public Affairs, Community Services Administration, Washington, DC 20506.

Background Information

Too often we focus on forms of conservation which are largely symbolic, like giving up the electric toothbrush. This is great, but actually, most of the energy consumed in the house goes to make raw heat. Obtaining this heat more efficiently and minimizing its loss is not as dramatic as a gadget diet, takes a lot more thought, costs more money, and requires continuing commitment. But the savings that can be achieved far exceed the toothbrush savings, even including the indirect energy costs of manufacturing such gadgets. (See appendix page 1-38)

We also believe the best way of teaching conservation techniques is to teach physical principles along with the techniques. Techniques change. In ten years some new kind of insulation may make all else obsolete, but houses will still lose heat by conduction, infiltration, and radiation. The

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spread treats conservation as a series of tips. We think students will retain the concepts longer if you are able to relate these tips to what the students know about heat flow, for example.

Activities and Discussion Questions

1. Look at the "Residential" block on page 23. What are the largest blocks? [Answer: the yellow "space heating;" the orange "water heating;" and the blue "other."] Together, how much of the total do space heating and water heating take up?]Answer: over half.]

This tells us that in the average home, space heating and water heating use most of the energy consumed. Is this true in your home? How could you find out?

2. What are some of the different ways heat can escape from a home?

One is conduction. Appendix p 8-5 provides a worksheet for calculating the heat escaping from windows. Appendix p 8-7 outlines an activity at home investigating insulation.

3. Energy can be conserved at home by using energy-efficient appliances. A lesson on the federally-mandated appliance labelling program will be found on appendix page 7-3.

Some Follow-up Activities at Home

1. With a parent's help, do an experiment to compare the cleaning power of hot and cold water in doing your family's laundry.

2. If you have a gas water heater, with a parent's help learn how to drain the sediment from the bottom of the tank. Let it settle and bring a bottle-full to school to show the class.

3. If you have a forced air heating system, with a parent's help find the filter and learn how to remove and examine it. Is it clogged? If it is, replace it and bring the dirty one to school to show the class.

4. If you have a leaky faucet, use a cup to catch the drips and calculate how many gallons of water are being lost in a day. (1 gallon = 16 cups).

5. If you have a dishwasher, with the help of a parent see if you can air dry the dishes by stopping the dry cycle and leaving the dishwasher door open over night. Do the dishes dry satisfactorily?

6. With a parent's help, try to think of at least two ways you could keep heat from escaping through your windows in the winter.

Some Consumer Research Projects

Assign groups of students to investigate and report on the following topics. Most of the research can be done by interviewing salespeople in stores, collecting product literature, and reading advertisements.

How do pilotless gas ranges, furnaces, and water heaters work?

Do gas water heaters really differ much in energy efficiency?

How does one read an appliance energy efficiency label?

How is caulking done? What kinds of caulk are available and how do they differ?

What is weatherstripping? What does it look like and how is it applied?

What are the different types of insulation?

Mini-Quiz

1. What is the biggest use of energy in the average home? [space heating]

2. What part of the house lets heat out most readily? [windows]

3. How do we stop warm air from escaping, or cold air form entering the house between the door and the door frame, or the window and the window frame? [by using weatherstripping]

4. How can you tell if the gasket on your refrigerator door is good? [It's good if it stops a playing card.]

True or False?

Lighting and heating a home evenly saves energy. [F]

CONSERVATION: ENERGY & HAPPINESS (pages 30 & 31)

Reading Level (by Fry count): 8th grade

Objectives

The student examines the relation between energy consumption and the quality of life.

Background Information

To many students, rising energy costs and the prospect of lower personal consumption imply a future lifestyle which may be far less satisfying than the one they now enjoy, or that their parents have enjoyed. To what extent does well-being, or the difficult to define "quality of life," depend on energy consumption? Or, put in its baldest form, is it true that the more energy you consume the happier you will be?

Energy is necessary for every good and service we use, including food. In general, the lower a nation's per capita energy consumption, the lower its per capita Gross National Product (GNP) and the lower its material standard of living. Historically, over the last thousand years the standard of living and energy consumption appear to have increased very roughly in parallel.

On the other hand, countries with the same per capita GNP may use significantly different amounts of energy per capita. The Swedes, for example, use less energy per capita than we do. (Allowances must be made for each nation's climate and mix of industries.) Also, in our own country for the last ten years the ratio of energy consumption to GNP has been declining. Between 1973 and 1979, industrial energy consumption rose by 3.2% and output rose by 17%. Perhaps most telling, in the consumer or industrial area it is hard to find examples of ways of doing smarter instead of doing without.

In considering this question, students can benefit from looking at thier immediate situation and how they might improve the efficiency of their own use of energy.

Activities and Discussion Topics

Because this reading covers a number of separate topics the suggestions are arranged by paragraphs of the reading.

1. The Main Theme: "Some people seem to believe..."

Solicit opinions from the class. Is this true? In what ways? To what extent?

Refer to the activity sheet on appendix page 8-3 for another view of this question.

2. Recreation as an example: "Some ways of having fun..."

Here is an activity you can use to produce a chart on the chalkboard that compares the energy-intensiveness of different forms of recreation with the class' opinion of how much fun they are.

Make a chart on the chalkboard with one wide column and two narrow ones. Ask the students to give you the names of different forms of recreation, such as different sports, hobbies, things they do with their family, TV and movie watching, and so forth. List these in the wide column. Get as diverse a list as possible. Be non-judgmental; try to include anything any individual feels is fun.

In the second column, have the class rate each recreation according to how much fun they feel it is, on a scale from one to five, with five being the most fun. Try to put about one fifth of the total number into each category. If one category gets too many members, you can rank the items by comparing them two by two, shoving the least or most fun off into adjoining groups, depending on which have two few items.

In the third column, have the class estimate how energy-intensive each form of recreation is, from A to E, E being most energy-intensive.

Now compare the two lists. Are 5's mostly E's? Could you have a good time if you were restricted to A's?

3. Transportation Costs and Benefits: "A quarter of all the energy..."

What forms of transportation exist in your community?
What are people's need for transport? Can they be categorized?
How feasible is travel by bicycle in your community?

4. Trash as a Waste of Energy: "A lot of the energy..."

Ask students to make a list of the things they throw away in a day. Be sure to include the things others throw away on their behalf, such as mother discarding food wrappings, etc.

Can the discards be categorized?

Are there more economical alternatives?

As a homework assignment, students can be asked to discuss with a parent the last time an appliance or car was replaced in their home. What considerations lead the parent to decide to replace the old appliance (or to acquire a new one). What considerations lead to the choice of the model purchased. What role, if any, did energy have in this decision making. To avoid intruding on family privacy, the assignment can just be to get a slip from the parent saying, "I have talked with my son/daughter about how we decided to replace an appliance or car."

5. Survivals: "In the past, we made certain choices..."

Can you think of any buildings, objects, or ways of doing things that are no longer functional but can still be found in your community. (For example, in many communities horse watering troughs can still be found.) Do any of these survivals involve energy consumption?

What will be the effect of increasing energy costs on existing patterns in your community? Any kind of patterns.

Mini-Quiz

1. Name a form of recreation that you enjoy that uses a lot of energy.

2. Name a form of recreation that you enjoy that uses very little energy.

3. Name three ways of going downtown from where you live, ranking them in order of the amount of energy you think would be consumed in carrying you downtown.

4. Name something you threw away in the last week.

5. Name two costs and two benefits of owning a car. Then name two costs and two benefits of taking the bus.

6. Name two costs and two benefits to the community of your owning a car. Name two costs and two benefits to the community of your being able to take the bus.

7. Name one machine in your home that you know is not as efficient as others on the market. Describe the alternative.

Homework Assignments

1. Make a list of "free" things available in the community. This might include not only paper bags but also public services like schooling, and use of the library and roads. Determine how each of these things is really paid for. Determine the energy implications of each of the free things.

2. A proposal has been made that the government provide low-income owners of old gasguzzler cars with no-interest auto loans on condition that they buy new, small, fuel-efficient American-made cars and that the old car is scrapped. Prepare for and against arguments and debate the proposal in class.

ENERGY SAVING AT WORK (page 32)

Reading Level (by Fry count): 7th-8th grade (borderline)

Objectives

The student recognizes that reducing the amount of energy used reduces the cost of doing business.

The student identifies waste heat as an unused energy source.

The student realizes that some conservation measures require capital investment.

Vocabulary

substitution

Background Information

This topic becomes much more real if you can relate it to a local industry. It is sometimes possible to persuade some from a factory to speak to the class. (This can even be done by telephone.) Many industries have engineers who are specifically responsible for the plant's energy consumption.

Another alternative is to relate this topic to the school plant, or to challenges in the home or community that parallel those of industry. The same basic principles of energy-saving apply.

Costs

What effect have rising energy bills had on home use of energy? A lesson on one aspect of economic incentives for conservation is found on appendix page 7-15.

Activities and Discussion Topics

Changes in materials

1. A few years ago there was a brief controversy over which used more energy, permanent-press Dacron-cotton shirts or all-cotton shirts. Let's think of the entire system the use of either product implies. What would energy uses would be necessary to make and use each of the shirts. Make a two lists on the chalkboard.

Thrifty Habits

On appendix page 8-13 is an exercise requiring students to think carefully of ways energy might be saved by careful management.

2. Can you think of other products where materials substitution has taken place, perhaps in an effort to save manufacturing costs? (An typical example is thread spools, which are now plastic instead of wood.) How could one estimate whether energy had been saved?

Interruptible Power

3. Are some uses of energy in a community more important than others? Do you think people could agree on the last use they would want cut off? What would it be?

4. Suppose you had to give up the use of some appliances in your home whenever energy was in short supply. Which appliances would you feel must be kept on? Which wouldn't matter? For which would cutting them off create a minor inconvenience? (Cutting off the freezer is a disaster, a clock is a minor inconvenience, a washing machinewell, the laundry can wait. There is a similiar spread in industrial processes.)

Can you think of any industrial processes where a temporary shutdown is very damaging? (an example to get started: film processing)

Using Waste Heat

5. What are some sources of waste heat in your home? How could they be utilized? (For example, in the winter, letting the hot water cool to room temperature after a bath before draining it saves a large number of furnace Btu's.)

Whole New Processes; Capital Investment

6. At home, if you had money to spend could you reduce your energy consumption. By doing what?

How do increasing costs motivate people to save energy?

Mini-Quiz

[Sorry, we couldn't think of any way of evaluating this topic using recall questions.]

1. Why would a utility offer lower prices to a firm that agrees its power can be cut off at any time?

2. Give one reason why, in the past, overseas companies were more interested than American firms were in finding ways to do things with less energy. [Energy was cheaper here.]

3. Suppose there are two firms, Firm A and Firm B, that make similar products that sell for similiar prices. Firm A uses twice as much energy as B per product made. Other things being equal, for which firm would you rather work? Why? [Firm B, if one argues that their costs are less and so your job is likely to be more secure. Or, one might answer Firm A, arguing that if they can sell the product for the same price now, and there is so much room for improvement in energy consumption, when they make the energy changes they will be able to undercut B's price.]

APPENDIX

This guide is part of a larger program which provides a sequence of lesson plans, almost all of which include activity sheets, worksheets, or readings, for an interdisciplinary course in energy at the junior high school level. No charge is made to schools for the materials; costs are borne by corporations in the state who are concerned about the next generation's understanding of energy.

The approach taken in the materials is:

quantitative (using SI units, with the exception of the calorie and Btu)

hands-on, emphasizing activities and investigations, and in the social studies, the use of primary source materials. To make it possible for individual students to use the activities and investigations, activity sheets and readings are as self-contained as possible, providing complete instructions and questions.

comprehensive The course follows the same sequence of ideas that is presented in the booklet you are using, though with some additions and a great deal more detail.

Because of space limitations in this guide, it has only been possible to give selections from the units, of which there are eight in all:

1. Energy Fundamentals
   - Energy has different forms
   - Energy can be converted from one form to another
   - Energy can be measured
     - Heat
     - Work
     - Electricity
     - Reading utility meters
     - Reading utility bills
   - First-Law Efficiency
   - Loss of available work with conversions

2. Energy From the Sun
   - Water cycle
   - Wind cycle
   - Photosynthesis
     - detecting chlorophyll, starch
     - measuring energy in food; calorimeter
   - Respiration
     - detecting seed respiration
     - detecting carbon dioxide before & after exercise
   - Food chains
   - U.S. Food system
   - Origin of fossil fuels

3. Fossil Fuels: History and Technology
   - Value of fuel illustrated historically
     - preparing raw materials: smelting
     - fuel as a source of work
   - Comparing wood and coal, 1300's
   - Coal and the Industrial Revolution
   - Drake's Well
   - Petroleum geology
   - Petroleum refining
   - Rise of the internal combustion engine
   - Comparing coal and gas, United States 1900
   - Pipelines
   - LNG
   - Cleaning up coal

4. Energy from Nuclear Fission
   - Atoms and elements,
   - Radioactivity
   - Transmutation
   - Isotopes and half-life
   - Fission and chain reactions
   - The lightwater reactor
   - Breeding
   - The uranium fuel cycle
   - Radiation and life
   - Risks
   - Comparing the uranium and coal fuel cycles

5. Renewable Energy Sources
   - Why renewables
   - Absorbing sunlight
   - Flat plate collectors
   - Water heater payback
   - Movement of the sun
   - Passive solar
   - Concentrating collectors: parabolas and rotisseries
   - Biomass: methane, alcohol
   - Directed student research reports

6. Energy in the United States
   - Energy in daily life through primary source materials, from outstanding authors and historical figures from 1605 to 1950
   - Review of energy transitions
   - Present sources and uses nationally
   - Present sources and uses household

7. Economics and Decision Making
   - What's Happening?!
   - Supply and demand
   - Comparing consumer alternatives
   - Present Value
   - Life-cycle costing

8. Conservation
    - What Can Conservation Do?
    - Conduction of heat in the home
    - Infiltration in the home
    - Water heating
    - Habits
    - Automobile
        - design features
        - driving habits
        - maintenence
    - Conservation and the Quality of Life

Energy Transformations

Worksheet

Energy can be converted from one form to another. We often need to do this when we use energy.

In each of the empty boxes below, write a way of converting energy from the form named on the left side to the form named at the top. An example is done for you. Some of the answers are easy; some are hard. Do as many as you can.

To This Form of Energy

How to Convert This Form of Energy

	heat	motion	light	electricity	chemical	nuclear
heat						
motion						
light						
electricity			light bulb			
chemical energy						
nuclear energy						

Making a Light Bulb

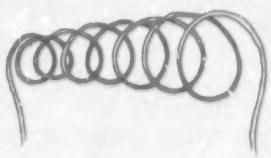
The incandescent light bulb has been in use since Thomas Edison introduced the first practical version in 1879.

Try to make a light bulb yourself. You will need:

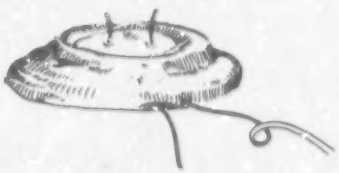
- ☐ wire for the filament
- ☐ wire for the connections
- ☐ a source of electricity, such as a dry cell
- ☐ a clear jar or cup
- ☐ modeling clay

Do you have all the things you need?

1. The filament: Take a piece of iron picture-hanging wire about 10 cm long. Unbraid it until you get a single strand of wire (share the other strands with your classmates). Wrap the wire around a pencil, pen, or other round object to form a coiled filament. Leave 2 cm of straight wire at each end. It should look like this:



2. The base: Flatten a piece of modeling clay big enough to cover the mouth of your jar. Stick the two bare ends of your connecting wires through the clay. The wires should be just as far apart as the filament is long. It should look like this:



3. Finishing the bulb: Attach the filament to the wires by wrapping the filament wires around the connecting wires. Put the globe over the filament and press it to the base. Check to be sure that the filament wire is still touching the connecting wire, and the connecting wires don't touch each other anyplace.

4. Light up!

Observations

1. Which part of the light bulb gives out light? _____

2. Is there evidence of any other form of energy besides light coming from the light bulb?

_____

_____

3. Trace the energy flow from a dry cell to a flashlight bulb. Four forms of energy should be listed.

_____ → _____ → _____ + _____

4. About how many years has the incandescent light bulb been in use? _____

bbl 92

Bulb
Soft glass is generally used. Hard glass is used for some lamps to withstand higher bulb temperatures and for added protection against bulb breakage due to moisture. Bulbs are made in various shapes and finishes.

Gas
Usually a mixture of nitrogen and argon is used in lamps 40 watts and over to retard evaporation of the filament.

Filament
The filament material generally used is tungsten. The filament may be a straight wire, a coil, or a coiled coil.

Support Wires
Molybdenum wires support the filament.

Lead-in Wires
Made of copper from base to stem press and nickel-plated copper or nickel from stem press to filament, they carry the current to and from the filament.

Button
Glass is heated during manufacture, and support and tie wires placed in it.

Button Rod
Glass rod supports button.

Tie Wires
Molybdenum support lead-in wires.

Heat Deflector
Used in higher wattage general service lamps and other types when needed, to reduce circulation of hot gases into neck of bulb.

Stem Press
The lead-in wires in the glass have an air-tight seal here and are made of a combination of a nickel-iron alloy core and a copper sleeve (Dumet wire) to assure about the same coefficient of expansion as the glass.

Fuse
Protects the lamp and circuit by blowing if the filament arcs.

Exhaust Tube
Air is exhausted through this tube during manufacture and inert gases introduced into the bulb. The tube, which originally projects beyond the bulb, is then sealed off short enough to be capped by the base.

Base
Typical screw base is shown. One lead-in wire is soldered to the center contact and the other soldered or welded to the upper rim of the base shell. Made of brass or aluminum.

Typical Incandescent Lamp

Courtesy of GTE Sylvania

Changing Light to Motion

Objectives

This lesson contributes to students' understanding of the following concepts:

Light heats objects which absorb it.

Light energy can be converted to motion.

Some light is not visible.

Heat is not a form of light.

Format of the Lesson

Introduction of radiometer

The more light, the faster it spins

How the radiometer works

Different forms of light

Comparison of infrared radiation with heat

Materials Needed

Crookes radiometer available from novelty stores, as well as scientific supply houses. (Edmund Scientific, Catalog #60,082, $5.95.) Providing each group with its own radiometer is helpful though expensive, since it gives individual students a chance to try the device for themselves.

source of visible and infrared light sunlight can be used for the visible light, but a more manipulable source is helpful. One can be made by using a lamp socket on the end of a cord. Some "trouble lights" are suitable, or make one by plugging a prong-to-socket adapter (.75¢) into an extension cord. A small reflector flood makes a good light. Convert it to infrared by adding a filter such as one from Edmund Scientific (Catalog #60,033), $4.95. Or use an ordinary flashlight; an infrared filter to fit a flashlight is also available from Edmund (Catalog #42,143) for $2.

Introducing the Radiometer

Set up the radiometer in a window (or direct a visible light source on it, though the window is better since, if students are not already familiar with the radiometer, using the window avoids "giving away" the connection with light). Ask students to describe what's happening. What kind of energy can be detected inside the glass bulb? (ANS: Motion, or mechanical energy.)

Where does this energy come from? How can we tell?

Compare the intensity of the light falling on the radiometer with its rate of rotation. Vary the light by shading the radiometer or placing it varying distances from the window or light source. Quantify the energy of motion by counting the number of rotations in 30 seconds. If several radiometers are available, ask groups of students to investigate different intensities.

Ask where the energy of the turning vanes comes from. Students will answer that it must be from light, since the vanes don't turn in the absence of light, and the more light there is, the faster the vanes turn.

How the Radiometer Works

What can be observed about the vanes? (ANS: They are black on one side; white on the other.)

Which absorbs more light, black or white? (ANS: Black.)

Which side of the vane is hotter? (ANS: The black side.)

Explain that there is air inside the radiometer (but at less than atmospheric pressure). The unequal heating of the vanes leads to a very small difference in air pressure at the surface of the vanes, which makes them rotate.

Please note that the explanation given by the manufacturer on the radiometer packaging (that molecules striking the black side bounce off with more energy, giving the vane a greater kick) is at best oversimplified and should not be used. The rotation of the radiometer is due to a phenomenon called thermal transpiration, in which gas creeps toward the hotter parts of the vane causing locally increased air pressure.

Refer students who want further information to the article "Radiometer" in the **Encyclopedia Britannica.**

Light Pressure—Optional Topic

With advanced students, you may wish to discuss the following additional information:

If all the gas could be removed from the bulb, and the bearing had even less friction, the vanes would turn in the opposite direction!

This would occur because of "light pressure." The photons of light are more strongly absorbed by the black side than the white side. In the space in front of the white side, the photons reflected from the white side are added to those streaming in, so there is a greater "density" of photons in front of the white side than in front of the black side. The greater pressure causes the radiometer to turn. In fact, however, it is not practical to demonstrate light pressure with radiometers of this design.

The effects of light pressure can be seen in the motion of comets' tails, which swing to point away from the sun. Light pressure is also of crucial importance in what happens inside stars.

A Light We Cannot See

Provide two artificial light sources, one of visible light and the other largely infrared. You can do this by putting a filter in front of a flood lamp, or by using a commercial heat lamp. Ask the students which light is brighter; they will choose the visible light.

As our earlier investigations with the radiometer showed, we can vary light intensity by adjusting distance. If you can darken the room, shine the two sources alternately on a piece of paper, moving the visible source farther and farther away from the paper, until an approximate visual balance is reached. Note the distances.

Now compare the strengths of the two light sources by shining them on the radiometer from the distances established in the visual comparison. The infrared source will cause the faster rotation. Why?

Point out that we cannot see all kinds of light. Visible light is only one part of the spectrum of radiation. All incandescent light bulbs emit a mixture of visible radiation and infrared radiation, but one of the bulbs we are using has been made to emit mostly infrared and little visible light. The radiometer is sensitive only to how much heat is produced by the absorption of the light, not to whether it is blue, red, yellow, or infrared light.

As it happens, infrared light is very strongly absorbed by objects, more so than visible light. We use infrared to heat everything from rooms to freshly painted automobiles. Sometimes it is called "radiant heat." But notice that it is really radiation, not heat. Only matter can have heat; infrared radiation can and does travel through a vacuum, just like the other radiation from the sun.

Projects for Independent Investigation

1. Some students may be interested in building other machines that convert light to motion as Crookes' radiometer does, using heat as an intermediary form.

NASA designed a solar motor that consists of a long metal tube painted black and pivoted on the ends. Sunlight can only hit one side at a time, so the lit side expands more than the shaded side, warping the tube. The warped tube is unbalanced; the bulge falls — bringing the cool side up. Now it expands, the bottom shrinks, and so on.

Clear directions for building such a motor are given on pages 50-54 of **Exploring Solar Energy**, by Thomas H. Metos and Gary G. Bitter (New York: Julian Messner, 1978). It is a fairly complicated project.

A second type of "solar engine" uses rubber bands or plastic strips, which contract when they are heated. Directions for building such an engine are given on pages 126-128 of the February, 1980, issue of **Popular Science** ("Build a Sun Tracker and a Solar Engine with Solar Muscle"). A different design, for a rubber band engine, can be found in the "Amateur Scientist" columns of the May, 1956, and April, 1971, issues of **Scientific American**. These are not as difficult to construct as the NASA motor.

2. What would happen if a spinning radiometer was placed in an environment that was colder than the vanes? Such an environment can be created. Choose a tin can higher than the radiometer and only a little bit larger in diameter, which the radiometer will fit into. Paint the inside of the can flat black. Glue it into the middle of a larger tin can. Pack the space between the two cans with ice and salt. After the cans have cooled, get the radiometer spinning as fast as possible in a strong beam of light, then quickly place it in the can. You can observe what happens by looking down on the radiometer from above. What does happen? Why?

3. A prism will split light into its various colors. Even though you can't see it, the prism also splits out the infrared. Can you devise a way of measuring the heat energy in the various bands of light, including the infrared? (Hint and caution: not all blacks are equal.)